



3<sup>rd</sup> Symposium on  
Occupational Safety and  
Health

Porto  
June 2019

DCE  
19

3<sup>rd</sup> DOCTORAL  
CONGRESS  
IN ENGINEERING

27 - 28 JUNE 2019  
FEUP  
PORTO - PORTUGAL

## TECHNICAL RECORD

**Title**

3<sup>rd</sup> Symposium on Occupational Safety and Health Proceedings Book

**Editors**

Olívia Pinho, J. Santos Baptista, Jacqueline Castelo Branco, Joana Duarte; Raquel Martins

**Publisher**

FEUP EDIÇÕES

**Date**

June 2019

**ISBN**

978-972-752-260-6

This book contains information obtained from authentic sources.

Reasonable efforts have been made to publish reliable data information, but the authors, as well as the publisher, cannot assume responsibility for the validity of all materials or for the consequences of their use.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation, without intent to infringe.

## ORGANIZING COMMITTEE

## Chairman

**Olívia Pinho** - University of Porto, Faculty of Nutrition and Food Science

**J. Santos Baptista** - University of Porto, Faculty of Engineering

## Members

**Jacqueline Castelo Branco** - University of Porto, Faculty of Engineering

**Joana Duarte** - University of Porto, Faculty of Engineering

**Raquel Martins** - University of Porto, Faculty of Engineering

**Sara Maheronnaghsh** - University of Porto, Faculty of Engineering

## International Scientific Committee

**Alfredo Soeiro** - University of Porto, Faculty of Engineering

**Ângela Fernandes** - Polytechnic Institute of Porto, School of Health

**António Sousa** - University of Algarve, Institute of Engineering

**António Torres Marques** - University of Porto, Faculty of Engineering

**Béda Barkokébas** - University of Pernambuco, Polytechnic School

**Evandro Broday** - Federal Technological University of Pará, Superior Magisterium

**Isabel Dias** - University of Porto, Faculty of Letters

**J. Santos Baptista** - University of Porto, Faculty of Engineering

**Jacqueline Castelo Branco** - University of Porto, Faculty of Engineering

**Joana Duarte** - University of Porto, Faculty of Engineering

**Joana Guedes** - University of Porto, Faculty of Engineering

**Joana Madureira** - University of Porto, Institute of Public Health

**Joana Santos** - Polytechnic Institute of Porto, School of Health

**João Rufo** - University of Porto, Institute of Public Health

**José Torres Costa** - University of Porto, Faculty of Medicine

**Liliana Cunha** - University of Porto, Faculty of Psychology and Education Science

**Laura Martins** - Federal University of Pernambuco

**Luiz Bueno da Silva** - Federal University of Paraíba

**Maria Luísa Matos** - University of Porto, Faculty of Engineering

**Mário Vaz** - University of Porto,

**Nélson Costa** - University of Minho, School of Engineering

**Olívia Pinho** - University of Porto, Faculty of Nutrition and Food Science

**Paula Carneiro** - University of Minho, School of Engineering

**Paulo Costa** - Federal University of Santa Maria

**Pedro Arezes** - University of Minho, School of Engineering

**Raquel Martins** - University of Porto, Faculty of Engineering

**Rui Melo** - University of Lisbon, Faculty of Human Kinetics

**Sara Ferreira** - University of Porto, Faculty of Engineering

**Sara Rodrigues** - University of Porto, Faculty of Nutrition and Food Science

**Susana Sousa** - Institute of Science and Innovation in Mechanical and Industrial Engineering

**Teresa Cotrim** - University of Lisbon, Faculty of Human Kinetics

## INDEX OF AUTHORS

A	
Abadi, Sara Shahedi Ali	103
Agostinho, Daniel	51

B	
Belinha, Jorge	10
Bumann, Niels	68
Bustos, D.	88, 96

C	
Carvalho, Susana	51
Castelo Branco, Jacqueline	115
Costa, Daniele	82
Costa, Humberto	110, 119

D	
Dinis, Fábio	46
dos Santos, Solange	123
Duarte, J.	5, 22, 27, 46, 61, 115, 123

F	
Fernandes, Adília	18
Ferraz, João	61

G	
Garreto, Carolina	5, 27, 115
Garreto, Gairo	73, 78
Gomes, Joana	10
Guedes, J. C.	82, 88, 96, 115, 123

L	
Lucena, A. D.	96, 123

M	
Maheronnaghsh, Sara	129
Martins, João Poças	46
Martins, R. P.	82
Mohammad Fam, Iraj	103
Morais, Simone	18
Mota, Antónia	73, 78

N	
Natal, Renato	10

O	
Oliveira, Marta	18

P	
Padrão, Patrícia	51
Pereira, Maria Carmo	18
Pereira, Pablo Monteiro	61
Pinho, Olívia	51, 61

R	
Ribeiro, Marcelo M.	34, 40, 119
Rosado, Ana Sophia	5, 27

S	
Sanhudo, Luís	46
Santana, Armanda	61
Santiago, Rui	1
Santos Baptista, J.	1, 22, 46, 61, 73, 78
Santos, Joana	129
Santos, Maria I.	34, 40
Shekarestan, Mojtaba	105
Sidani, Adeeb	46
Silva, Radigande	34, 40
Silva, Trajano F. B. X.	40, 110, 119
Slezakova, Klara	18
Sobrinho, António Dickson	56
Soeiro, Alfredo	46

T	
Teixeira, João Paulo	18
Torres Costa, J.	1, 22, 88
Torres Marques, António	1, 73

U	
Uachisso, Arminda	51

V	
Vaz, Mário	22, 56, 78, 129

## SUBMITTED PAPERS – by submission order

Analysis of the instrumentation used in randomized controlled trials to assess pain in the osteopathic intervention: A short review .....	1
Analysis of a chicken wing cut sector using the OWAS method .....	5
Chitosan nerve guidance channels with different geometries and their numerical analysis.....	10
Assessment of firefighters' occupational exposure to polycyclic aromatic hydrocarbons by biomonitoring.....	18
Occupational exposure to dust in the mining industry context – a short review.....	22
OWAS method analysis applied to a slaughterhouse company .....	27
Prevalence of occupational diseases in women in Universities: Review Article.....	34
Suicide and Work, Sociological View. Review article .....	40
Virtual Reality and the future of construction .....	46
Analysis of the nutritional composition of the typical meals of the rural workers in the Muanza District in Sofala – Mozambique .....	51
The Posted Workers and their difficulties in European Union.....	56
Food in the occupational environment and its benefits in worker's health.....	61
Specific Risks associated with the Manufacture of Airplanes.....	68
Hand tools characteristics in slave labour.....	73
Thematic review on the slaves' feeding in colonial and imperial Brazil .....	78
Predicting thermal sensation through local body skin temperatures to assess thermal comfort: a short systematic review .....	82
A short review on physiological monitoring during working activities.....	88
A comparison of energy expenditure equations for basal-equivalent activities .....	96
Quantitative Risk Analysis and Consequence Modeling the Explosion of Methane Storage Tanks in a Gas Refinery.....	103
The sound aesthetic of servicescape: influence in the aesthetic experience of employees ....	110
Geographic information Systems enforced to Occupational Health and Safety Practices: A short literature review.....	115
Work accidents with biological material with health professionals in Brazilian hospitals .....	119
Ergonomic analysis of cleaning professionals: pilot study.....	123
Factors influencing workplace physical activity interventions: a short review .....	129



# Foreword

The 3<sup>rd</sup> Occupational Safety and Health proceedings book is a compilation of the most recent works of students, researchers and professors within the domain of occupational safety and health. The included works are focused on selected topics regarding ergonomics, safety, and health.

This proceedings book represents the state of the art and it is mainly based on research carried out at Universities and other research institutions, as well as some case studies. In its scope, this book contains useful and up-to-date information, giving visibility to emerging issues and presenting new solutions in the field of occupational safety and health.

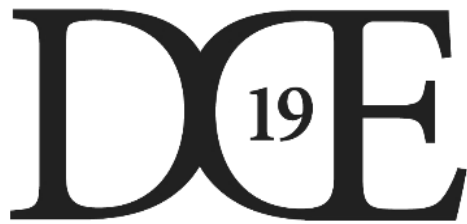
The proceedings books is based on selected contributions from the 3<sup>rd</sup> Doctoral Congress in Engineering, held on the 27<sup>th</sup> and 28<sup>th</sup> of June, at Faculty of Engineering of University of Porto, in Porto, Portugal. All the included contributions were revised by, at least, 2 of the 31 international scientific committee members.

The Editors would like to take this opportunity to thank all the authors for their contribution, to all Faculties of the University of Porto that supported the Symposium on Occupational Safety and Health of the Doctoral Engineering Congress, as well as all members of the Scientific Committee on behalf of following institutions: Institute of Science and Innovation in Mechanical and Industrial Engineering (INEGI), Polytechnic Institute of Porto, Institute of Public Health of the University of Porto, University of Lisbon, University of Minho, University of Algarve, University of Pernambuco, Federal University of Paraíba, Federal University of Pernambuco, Federal University of Santa Maria, and Federal University of Technology – Paraná.

Porto, June 2019

Symposium Organizing Committee





3<sup>rd</sup> DOCTORAL  
CONGRESS  
IN ENGINEERING

## SUBMITTED PAPERS



# Analysis of the instrumentation used in randomized controlled trials to assess pain in the osteopathic intervention: A short review

Rui José Santiago<sup>1</sup>, António Torres Marques<sup>2</sup>, J. Santos Baptista<sup>3</sup>, J. Torres Costa<sup>4</sup>

<sup>1</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (rui.santiago@gmail.com) ORCID 0000-0002-8227-5707, <sup>2</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (marques@fe.up.pt), <sup>3</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (jsbap@fe.up.pt) ORCID 0000-0002-8524-5503, <sup>4</sup> Faculty of Medicine, University of Porto, Porto, PT (zecatoco@sapo.pt)  
[https://doi.org/10.24840/978-972-752-260-6\\_0001-0004](https://doi.org/10.24840/978-972-752-260-6_0001-0004)

## Abstract

**Introduction:** Osteopathy is an emergent health-care profession, present in most of the developed world and since 2013, regulated in Portugal. Osteopaths intervene in a range of health issues in which pain is a very common aspect. Pain is a worldwide problem, affecting all aspects of society. Measurement of pain objectively is yet not possible; even considered unreliable in many circumstances, the standard is self-reported questionnaires. A variety of different scales were used to measure the intensity of pain in Osteopathic research; however, the criteria of the options are not always clear or reported. This review aims to analyze and critically compare the different characteristics of the most used questionnaires by osteopathic researchers for assessing the intensity of pain in randomized controlled trials (RCT).

**Methodology:** A literature search was conducted using 7 electronic databases. This search was conducted for RCT articles studying the efficacy/effectiveness of the osteopathic manipulative treatment (OMT) intervention in pain. The findings followed the PRISMA statement. Included studies were assessed for the risk of bias (RoB) using the Jadad score. Results and Discussion: 123 studies were identified, and after removal of duplicates and application of the eligibility criteria, 21 articles were included for this review. Nine studies used the Visual Analogue Scale (VAS) 10cm scale, seven the Numeric Rating Scale (NRS) 11 points scale, the remaining used other options. Although similar, there are differences in these two scales that may affect the outcomes. Justification of the choice of the evaluation instrument was not always present and not associated with the methodology and the target population. The overall quality of the studies, in terms of RoB, was considered good. Conclusion: VAS and NRS are the choices of most authors. Authors in Osteopathy, or other health care professions should be very clear about the reasons behind the choices for measuring the intensity of pain; these should fit the objectives and study design.

**Keywords:** Osteopathic intervention, Pain scales, Assessment of pain.

## INTRODUCTION

Osteopathic medicine is a healthcare form centered in the patient rather than on the disease. The professional of Osteopathy intervenes through a range of manual techniques within the Osteopathic Manipulative Treatment (OMT) to support homeostasis and improve physiologic function, as well as advise in lifestyle, diet, counseling, posture and physical activity (WHO, 2010). Osteopathic medicine is regulated in more than 15 countries, including the United States, Canada, Australia, New Zealand, and 8 European countries, among them is Portugal, since 2013, it is also being taught in higher education in Portugal, since 2016 (OIA, 2013; FORE, 2018). Still, this world-wide emergent primary care health profession needs more evidence-based support for its claims and secure its place within the health care professions. Due to the myriad of contexts necessary to study to have a more informed decision if Osteopathic Manipulative Treatment (OMT) is the best clinical option, more studies should be designed and implemented to understand its effectiveness and or efficacy in general symptoms and pain particularly. Every year, millions suffer from acute or chronic pain, having a considerable impact on costs and budgets for any country as it affects work productivity and demands resources for health care, prevention, and rehabilitation. In the USA alone, chronic pain affects 100 million people, and it costs society at least \$560-\$630 billion, every year (AAPM, 2018). Attempts to understand and define pain are one of the oldest challenges of medicine and other subjects once it plays a crucial role in culture and identity (Raffaelli and Arnaudo, 2017). The measurement of pain in clinical research of musculoskeletal disorders (MSD's) has been a central question that many medical specialities tried to explore. Self-reporting assessment of pain is still the 'gold-standard' but,

according to Cowen et al., (2015), to process external information and report such personal experience may be unreliable in many circumstances. The objective of this review is to analyze the different tools used in the last five years to assess pain in studies analyzing the efficacy or effectiveness of the osteopathic intervention. For this work, pain is not subject to location, pathology, or another contextual variable. To the author's knowledge, this is the first critical systematic review to appraise the use of these measuring systems used to quantify the intensity of pain in Osteopathic interventions in Randomized Controlled Trials (RCT).

## **METHODOLOGY**

Literature searches were performed from the 3<sup>rd</sup> to the 10<sup>th</sup> of March of 2018 to identify all randomized controlled trials (RCT's) where the pain was one of the outcomes of the analysis of efficacy or effectiveness for the OMT intervention. The research methods and reporting of this study followed the PRISMA guidelines (Liberati et al., 2009).

### Search Strategy

Twenty-one Relevant studies were identified through a comprehensive bibliographic search on the following electronic databases: SCOPUS, Cochrane Central Register of Controlled Trials, MEDLINE, PEDro, OSTMED.DR, Science Direct and Web of Science. The terms searched were osteopath\*, Randomized Controlled Trial OR RCT, Pain, Efficacy OR Effect\*. The combination of terms used was adapted to the different database search engine specifications. Duplicated records from the searches were identified and removed. The authors considered that searching for the last five years was appropriate for the objectives of this work.

### Eligibility criteria

The search limits applied after the removal of duplicates were: (1) Published before 2012; (2) Not published in English; (3) Full paper not accessible; (4) Participants not human and (5) Subject out of theme. The Eligibility criteria applied was: (1) The study must include the application of OMT, not only a single technique; (2) Randomized and Controlled Trials study design exclusively and must assess for efficacy or effectiveness of the OMT intervention; (3) Study outcomes must include pain and use subjective or objective measurements; (4) Study must be approved by an Ethics Committee or state the use of written consent.

### Risk of Bias

The included trials were assessed for their individual Risk of Bias (RoB) using the five-point Jadad score (Jadad et al., 1996).

### Data Synthesis

Findings of this review were summarised in narrative form, and data reported as means and percentages.

## **RESULTS**

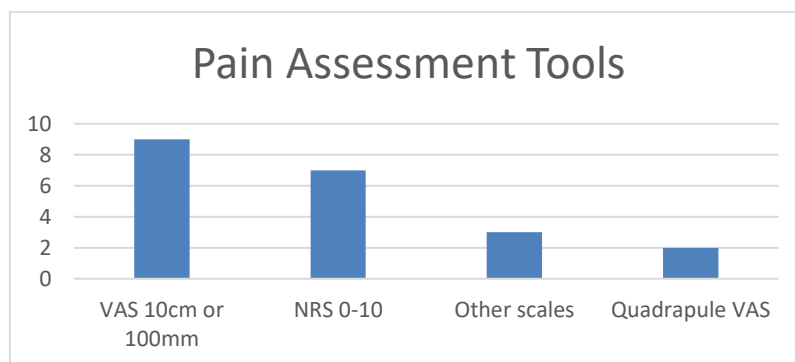
### Study Selection

The search strategy for the current review identified 527 articles, all from database searching. Selection based on relevance to the topic and the exclusion of duplicates left 123 articles. After

reading the full text and applying the inclusion criteria to all selected publications, 21 articles were included in this analysis.

### Pain Assessment

All the assessment methods of pain in the RCTs included in this article were all in the format of questionnaires and therefore, subjective. The results of this study show that there is a predominance of the use of different models of the VAS and the NRS scores, as shown in Figure 1. Most authors did not present a justification for their choice of scale.



**Figure 1.** Represents the incidence of use of each of the pain assessment tools in the included studies.

## **DISCUSSION**

### Subjective measurement of pain

At least 30 different instruments have been used for the past 30 years in the attempt to measure pain. The most commonly used have been VAS, the NRS and Verbal Radical Scale (VRS) but translating these results into useful patient information is more of an art than a science (Zanoli et al., 2002). Hjermstad et al., (2011), concluded that VAS, NRS-11, and VRS-7 all work well for pain intensity. According to this author, the relevant choice is not the type of scale, but the conditions associated, the standardization of anchor descriptors, methods of administrations, time frames, interpretation of cut-offs and clinical significance. In a more recent review of the pain scales in adults, by Karcioğlu et al., (2018), the same three questionnaires were compared, and all were reported as valid and reliable. VAS was considered more difficult than the others. The elderly and those with cognitive impairments, communication problems and minorities have found verbal descriptor or rating scales more practical than others.

### Comparison of VAS and NRS

Hawer et al., (2011) described all the questionnaires used for assessing pain in rheumatologic, adult patients, but these same questionnaires have been widely used for pain in other populations. Among them are, VAS and NRS, the two described as generic, one-dimensional pain questionnaire. These were the two most used questionnaires in the included studies; both are widely used and reliable for pain intensity, not the pain experience. NSR has the advantages of being administered both verbally and in writing, the simplicity of the scoring (no need to take measures) and it is equally reliable in the literate and illiterate participant.

## CONCLUSIONS

These results show that the Visual Analogue Scale 10cm and Numeric Rating Scale 11-point were the options of most authors studying the efficacy or effectiveness of OMT in the intensity pain using RCT methodology. These two questionnaires have a few differences that can potentiate a more accurate use depending on the type of population and the study design. The authors recognize limitations in selection of studies, in the time frame of 5 years, papers and in excluding non-English works. Future research in Osteopathy for the intensity of pain should justify the choice of a survey to meet the study design and the specific aspects of the outcomes towards a better-informed practice.

## References

- AAPM. (2018). Facts and Figures on Pain. Retrieved from <http://www.painmed.org/patientcenter/facts-on-pain/>
- Cowen, R., Stasiowska, M. K., Laycock, H., & Bantel, C. (2015). Assessing pain objectively: the use of physiological markers. *Anaesthesia*, *70*(7), 828-847. doi:10.1111/anae.13018
- FORE. (2018). REGULATION OF OSTEOPATHY IN EUROPE. Retrieved from <https://www.forewards.eu/regulation/>
- Hjermstad, M. J., Fayers, P. M., Haugen, D. F., Caraceni, A., Hanks, G. W., Loge, J. H., . . . European Palliative Care Research, C. (2011). Studies comparing Numerical Rating Scales, Verbal Rating Scales, and Visual Analogue Scales for assessment of pain intensity in adults: a systematic literature review. *J Pain Symptom Manage*, *41*(6), 1073-1093. doi:10.1016/j.jpainsymman.2010.08.016
- Jadad, A. R., Moore, R. A., Carroll, D., Jenkinson, C., Reynolds, D. J., Gavaghan, D. J., & McQuay, H. J. (1996). Assessing the quality of reports of randomized clinical trials: is blinding necessary? *Control Clin Trials*, *17*(1), 1-12.
- Karcioglu, O., Topacoglu, H., Dikme, O., & Dikme, O. (2018). A systematic review of the pain scales in adults: Which to use? *Am J Emerg Med*, *36*(4), 707-714. doi:10.1016/j.ajem.2018.01.008
- Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gotzsche, P. C., Ioannidis, J. P., . . . Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med*, *6*(7), e1000100. doi:10.1371/journal.pmed.1000100
- OIA. (2013). *History and Current Context of the Osteopathic Profession*. Retrieved from <http://oialliance.org/resources/oia-status-report/>
- Raffaelli, W., & Arnaudo, E. (2017). Pain as a disease: an overview. *J Pain Res*, *10*, 2003-2008. doi:10.2147/JPR.S138864
- WHO. (2010). Benchmarks for Training in Traditional/Complementary and Alternative Medicine, Benchmarks for Training in Osteopathy. Retrieved from [www.who.int/medicines/areas/traditional/BenchmarksforTraininginOsteopathy.pdf](http://www.who.int/medicines/areas/traditional/BenchmarksforTraininginOsteopathy.pdf)
- Zanoli, G., Strömqvist, B., Jönsson, B., Padua, R., & Romanini, E. (2002). Pain in low-back pain: Problems in measuring outcomes in musculoskeletal disorders. *Acta Orthopaedica Scandinavica*, *73*(sup305), 54-57. doi:10.1080/000164702760379576



## Analysis of a chicken wing cut sector using the OWAS method

Ana Sophia Rosado<sup>1</sup>, Carolina Garreto<sup>2</sup>, J. Duarte<sup>3</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT (anasgmr@yahoo.com.br) ORCID: 0000-0002-4935-4171, <sup>2</sup>Faculty of Engineering, University of Porto, PT (carolgarreto@gmail.com) ORCID 0000-0001-7138-7714, <sup>3</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (jasduarte@fe.up.pt) ORCID 0000-0002-5856-5317  
[https://doi.org/10.24840/978-972-752-260-6\\_0005-0009](https://doi.org/10.24840/978-972-752-260-6_0005-0009)

### Abstract

**Introduction:** The Industrial Revolution has encouraged consumption and, consequently, the competitiveness of the market. Historically, it can be perceived as the evolution of the industrial process. However, despite the implementation of automation, many industrial activities continue to be repetitive and monotonous, such as the first industries in which maximum production was required at the lowest cost. The still persistent production model can cause physical stress by the uninterrupted repetition of movements and force requirement, and psychological stress due to monotony and overloads. Despite the improvements in working conditions and awareness about the importance of occupational health and safety, there is too much charge about the goal, productivity and product quality, factors that cause stress physical and psychological to the worker. The physical stress tends to favor the development of musculoskeletal injuries that, when occurring in the workplace, are called occupational diseases. The objective of this research was to observe the work position especially the posture adopted by the workers in a chicken wing cut sector. **Methodology:** The observation allowed the ergonomic analysis with the use of the Ovako Working Posture Analyzing System (OWAS) method and subsequent comparison of the results obtained to the reality experienced by the workers, namely, the index of musculoskeletal injuries in the sector. For the research, the observation in situ of the activities was performed and the ergonomic risk was evaluated by the OWAS method to assess the ergonomic risks of the postures based on the position of the back, arms, and legs in an industrial sector which activity is exclusively the cut of the chicken wing. **Results and discussion:** The analysis of the times and methods, as well as the medical records of all the workers of the sector, were registered and assessed. For statistical analysis, workers were divided into a) uptime, b) workers who had already exercised demanding work activity of physical exertion and/or repetition of movements and the form of removal (with medical low or without medical low) and, c) by gender. It was observed the ergonomic risk of activity by the OWAS method and the percentage of injured workers, which was possible by analyzing the medical records. There was disagreement between the result of the ergonomic method and the number of injured workers. It is believed that this happened since the method does not consider the repetition of movements that is exhaustive in the activity. **Conclusions:** It was also found that the same activity performed in identical conditions tends to be more harmful to females. Since the ergonomic analysis is performed using several tools, it is believed that the result is reliable, given the dissonances that may exist between methods and means of analysis.

**Keywords.** Occupational disease, Work-related musculoskeletal disorders, Posture.

### INTRODUCTION

Most of the work-related musculoskeletal disorders (WMSD) develop over time. Usually, there is no single cause for these injuries (EU-OSHA, 2019). The WMSD are associated with certain types of activity, Santos (2015) suggests that the main occupational risk factors originating in the work activity are posture, repeatability, strength, and exposure to vibrations. WMSD are lesions that have different factors in their origin and their symptomatology is a direct or indirect consequence of morphological and functional alterations that are induced in the motor, sensory and neurovegetative system (Ranney, 2000). Succinctly, it can be said that WMSD are lesions that result from the action of professional risk factors such as repeatability, overload and/or posture adopted during work (Uva, Carnide, Serranheira, Miranda, & Lopes, 2008). WMSD are considered occupational diseases as it falls within the definition: "Illness contracted by the worker following exposure to one or more risk factors present in the professional activity, working conditions and/or techniques used during the work" (Direção-Geral da Saúde, 2014). WMSD is usually due to muscular fatigue, which is the effect of continuous work, which causes a reversible reduction of the organism's capacity, being caused by a set of factors (Iida, 2005). In order to elide or minimize the incidence of WMSD, there are in-depth studies on ergonomics, which is the science that studies "the adaptation of work to man" (Crespaumer, Brito, Melo, & Correa, 2015). The ergonomic analysis of jobs is a method for defining and evaluating working conditions. A general assessment may lead to deeper analysis or correction of unsatisfactory

working conditions (Costa, 2004). Ergonomics is seen as the application of the biological sciences in conjunction with the engineering sciences to achieve the optimum adjustment of the human being to their work and to ensure, simultaneously, efficiency and well-being (Superior, Empresariais, Guterres, & Sobral, 2014). Abranches (2005) adds that ergonomics has an interdisciplinary character that deals with the optimization of working conditions aiming at an integrated approach of the safety, health, and comfort of the worker and the efficiency of the quality and quantity of production. The ergonomic analysis aims to verify and, if possible, to rebut or minimize adverse situations to the musculoskeletal structure of the worker because they can result in decreased productivity, which is essential in the current market conjuncture increasingly competitiveness (Cohn, Hirano, Karsch, & Sato, 2015). The objective of the study is to evaluate the postures adopted by the workers in order to verify the risks of developing musculoskeletal injuries and to compare the result to the reality experienced through the analysis of medical records.

## METHODOLOGY

The study analyzed the chicken wing cutting sector, in a slaughterhouse located in southern Brazil. The company has a population of 1300 employees, 40 of them working in the wing cutting sector (20 workers per shift). It is important to emphasize that the population analyzed consists of 66.7% of female and 33.3% of male, with a mean age of 36 and 40 years old respectively. All workers had their medical records evaluated. However, the postural observation was performed to, approximately, one-third of them, emphasizing that all the workers perform the function exactly the same way. The company has two production shifts, including three pauses of 20 minutes and 1 hour for lunch break, as observable in Table 1.

Table 1. Shifts and pauses

Work shift start	1 <sup>st</sup> break	2 <sup>nd</sup> break	Lunch break	3 <sup>rd</sup> break	Work shift end
4:00 a.m.	5:40 a.m. to 06:00 a.m.	07:40 a.m. to 08:00 a.m.	09:40 a.m. to 10:40 p.m.	12:00 to 12:20	1:29 p.m.
2:00 p.m.	3:40 p.m. to 4:00 p.m.	5:40 p.m. to 6:00 p.m.	7:40 p.m. to 8:40 p.m.	10:00 p.m. to 10:20 p.m.	11:30 p.m.

The analysis was developed in January 2017 through sector observation *in situ*, and photographic record. The chosen instrument to do so was the *Ovako Working Posture Analyzing System* (OWAS) method which aims to generate information to improve working methods by identifying harmful body postures during the performance of activities (Másculo & Vidal, 2011). The OWAS Tool offers a simple method for analyzing work postures. The results generated are based on the positioning of the spine, arms, and legs, as well as considering the loads and forces used. The method was used in its original form, including the spine, arms, and legs, as well as the carry of loads or use of force, after the observations of the postures of approximately 14 workers (one-third of all employees in the sector) in a slaughterhouse, crowded in the wing cutting sector. The score attributed to the evaluated posture indicates the urgency in taking corrective measures to reduce the exposure of workers to risks (Masculo & Vidal, 2013). The method scores in ascending order of severity according to the value assigned to the back and arms from 1 to 3, and the legs score from 1 to 7. The force performed by the worker (the knife weight used do cut the wing) was also analyzed. Therefore, to each posture assumed by a

worker, it was attributed a 4-digit code that depended on the classification within the previous postures for each part of the body, and the respective load (Gómez-Galán, Pérez-Alonso, Callejón-Ferre, & López-Martínez, 2017). After analyzing the body and the force, the general table of scores is used. The intersection of the results obtained will generate a final numerical risk result from 1 to 4, being 1 considered a normal posture and 4 a posture that requires immediate attention. The medical records of the workers of the chosen industrial sector responsible for the cutting of chicken wings were also analyzed, with the objective of verifying the incidence of musculoskeletal injuries and highlighting the more evident results. The most relevant data analyzed were sex, age, admission (uptime), medical leave, days, ICD (International Code of Diseases), social security benefits, previous function, period worked. The data obtained allowed a statistical perception of the population most affected by musculoskeletal disorders.

## RESULTS AND DISCUSSION

In the company under analysis, an average slaughter of 50,000 chicken per shift is made. The work pace is 7,500 products per hour, which equals 125 products per minute. Considering that each product has 2 wings it equals 250 products per minute. There are 20 employees in the sector per shift (in the wing cutting machine), so the pace of work per employee is 12.5 products every minute; each product has 2 wings, which means 25 cuts per minute, per employee. The weight and dimensions of the knife used are negligible for the analysis. The force exerted by the workers in the execution of the wing cut was not measured. However, by the simple analysis, it was realized that it is enough to lean the knife in the skin of the animal so that the cut occurs. The collaborators position themselves standing in front of the products, with no back rotation. As for the position of the upper limbs, the arms move up and down continuously. The scores obtained with the application of the OWAS method are presented in Table 2.

Table 2. OWAS method results

<b>Task: WING CUTTING</b>		
<b>Body part</b>	<b>Position</b>	<b>Pontuation</b>
<b>Back posture</b>	Upright	1
<b>Forearms</b>	One above elbow joint	2
<b>Legs</b>	Standing with one leg upright	2
<b>ANALYSIS RESULT</b>		1

Regarding the statistics of the occupational diseases, the medical records were used, having been considered: employees with less than two years in the company, two to five years and more than five years. Moreover, other situations such as workers with a medical certificate without social security clearance (period less than 15 days), with a social security clearance (period exceeding 15 days) and workers with previous demanding functions of the upper limbs were verified. Figure 1 shows the incidence of musculoskeletal injuries in women and Figure 2 depicts the incidence in men. By the statistical analysis made with the data from medical records, it was found that 25% of the women hired by the company between 2 and 5 years had clearance with medical certificate due to musculoskeletal injuries of the upper limbs, a very harmful impact on productivity. Considering the same period – 2 to 5 years – in the male

population, there were 8% of injured patients with medical leave. Although the withdrawal period was longer than in the female population, the index of injured men is significantly lower.

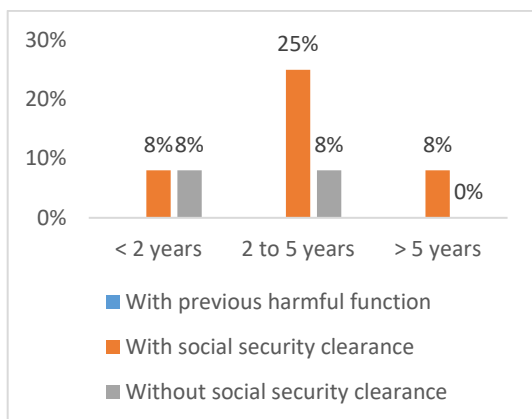


Figure 1. Injured women

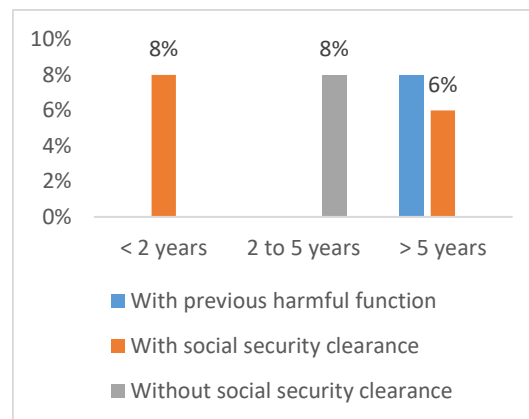


Figure 2. Injured men

Although the result of the analysis by the OWAS method was at risk level 1 (normal posture), there is activity movements repetition of the upper limbs throughout the working day. The repetition of movements is not considered in OWAS analysis. In this sense, Pedro & Martins (2009) describe it as an observational method to evaluate spine posture, upper and lower limbs and muscular strength involved. There is no information about the cadence of the cycle and repetition of movements. Regarding musculoskeletal injuries, studies have shown that the incidence is higher among young workers, with women being the most affected, with a prevalence of between 20 and 39 years (Walsh et al., 2004). Another study in a slaughterhouse about the risks of musculoskeletal injury concluded that most of the collaborators presented some type of pain, most of them in the upper limbs (Pereira, Fernandes, Ramos, & Taque, 2016). The present study showed that women with mean age 36 are the most affected and also that many workers felt some pain throughout the contractual.

## CONCLUSIONS

The ergonomic analysis by the OWAS method considered that the adopted posture is ergonomically normal. However, the analysis of medical records showed that in the sector there is an incidence of musculoskeletal injuries, especially in the female population. The analysis by the used ergonomic method provides data of interest, but it is not enough. Knowing that the human body is not an exact machine, it is important that the analysis is accompanied by other complementary methods. It is believed that the lesions occurred by the exhaustive repetition of movements of the upper limbs since the repetition of movements is not considered in the analysis of the OWAS method. By the analysis of medical records, it can be said that the female population tends to be injured more frequently. There are studies that emphasize the fragility of female physical complexion as compared to men, which would bring damage to the musculoskeletal structure when subjected to the same activity, effort, and conditions. The results obtained by the OWAS analysis and by the medical records were divergent since both have a different focus of analysis. This indicates that the analyses should use more than one method so the result can be reliable and conducted more accurately. It was concluded that it is

necessary to communicate with the workers and to raise awareness about occupational diseases (Pereira et al., 2016).

## References

- Abranches, S. S. (2005). *A situação ergonômica do trabalho de enfermagem em unidade básica de saúde*. *Ergonomia*. UNIVERSIDADE DE SÃO PAULO ESCOLA. <https://doi.org/10.11606/T.22.2005.tde-07122005-104056>
- Cohn, A., Hirano, S., Karsch, S. U., & Sato, A. (2015). DA REVOLUÇÃO INDUSTRIAL AO MOVIMENTO OPERÁRIO: As origens do mundo contemporâneo.
- Costa, L. G. (2004). Guia do Finish Institut of Occupational Health para Análise Ergonômica de Postos de Trabalho. Retrieved from [http://www.crpq.pt/empresas/recursos/kitergonomia/Documents/EWA\\_Português\\_2004.pdf](http://www.crpq.pt/empresas/recursos/kitergonomia/Documents/EWA_Português_2004.pdf)
- Crespaumer, V., Brito, F., Melo, C., & Correa, A. (2015). Aplicação Do Método Owas E Análise Ergonômica Do Trabalho Em Um Segmento De Uma Empresa De Grande Porte Situada No Mucínio De Campos Dos Goytacazes. XXXV Encontro Nacional de Engenharia de Produção.
- Direção-Geral da Saúde. (2014). Programa Nacional de Saúde Ocupacional. Retrieved March 11, 2019, from <https://www.dgs.pt/saude-ocupacional/doencas-profissionais-e-acidentes-de-trabalho/doencas-profissionais.aspx>
- EU-OSHA. (2019). Lesões musculoesqueléticas. Retrieved March 14, 2019, from <https://osha.europa.eu/pt/themes/musculoskeletal-disorders>
- Gómez-Galán, M., Pérez-Alonso, J., Callejón-Ferre, Á.-J., & López-Martínez, J. (2017). Musculoskeletal disorders: OWAS review. *Industrial Health*. <https://doi.org/10.2486/indhealth.2016-0191>
- Iida, I. (2005). *Ergonomia: projeto e produção*. São Paulo: Editora Edgard Blucher.
- Másculo, F. S., & Vidal, M. C. (2013). *Ergonomia: trabalho adequado e eficiente*. Elsevier Brasil.
- Másculo, F. S., & Vidal, M. C. (2011). *Ergonomia - Trabalho Adequado e Eficiente - Francisco Soares Másculo; Mario Cesar Vidal*. Elsevier Brasil.
- Pereira, J. A. da S., Fernandes, T., Ramos, M. T. S., & Taque, C. M. W. (2016). OS RISCOS DE LER / DORT NA DESOSSA DE UM ABATEDOURO BOVINO, 100–110.
- Ranney, D. (2000). *Distúrbios osteomusculares crônicos relacionados ao trabalho*. São Paulo: Roca. São Paulo.
- Santos, A. R. V. (2015). *Lesões musculoesqueléticas relacionadas com o trabalho nos enfermeiros em contexto hospitalar*. Escola Superior de Enfermagem de Coimbra.
- Superior, E., Empresariais, C., Guterres, M. J., & Sobral, C. (2014). *Instituto Politécnico de Setúbal Análise e Intervenção Ergonômica em Postos de Trabalho com Computadores: A Perceção dos Trabalhadores*. Instituto Politécnico de Setúbal. Retrieved from [https://comun.rcaap.pt/bitstream/10400.26/6657/1/Dissertação\\_SHT\\_MariaJoaoSobral\\_FINAL.pdf](https://comun.rcaap.pt/bitstream/10400.26/6657/1/Dissertação_SHT_MariaJoaoSobral_FINAL.pdf)
- Uva, A., Carnide, F., Serranheira, F., Miranda, L., & Lopes, M. F. (2008). Lesões Musculoesqueléticas Relacionadas com o Trabalho: Guia de Orientação para a Prevenção. *Programa Nacional Contra as Doenças Reumáticas*, 28. <https://doi.org/274779/08>
- Walsh, I. A. P., Corral, S., Franco, R. N., Canetti, E. E. F., Alem, M. E. R., & Coury, H. J. C. G. (2004). Capacidade para o trabalho em indivíduos com lesões músculo-esqueléticas crônicas. *Revista de Saude Publica*, 38(2), 149–156.

# Chitosan nerve guidance channels with different geometries and their numerical analysis

Joana Gomes<sup>1</sup>, Jorge Belinha<sup>2</sup>, Renato Natal<sup>3</sup>

<sup>1</sup>Institute of Science and Innovation in Mechanical and Industrial Engineering (INEGI), Faculty of Engineering, University of Porto, PT (joanamsgomes@gmail.com) ORCID 0000-0002-6250-340X, <sup>2</sup>School of Engineering, Polytechnic of Porto, PT (job@isep.ipp.pt) ORCID 0000-0002-0539-7057, <sup>3</sup>Faculty of Engineering, University of Porto, PT (rnatal@fe.up.pt) ORCID 0000-0002-7281-579X  
[https://doi.org/10.24840/978-972-752-260-6\\_0010-0017](https://doi.org/10.24840/978-972-752-260-6_0010-0017)

## Abstract

**Introduction:** Peripheral nerve injuries are a major cause of permanent disabilities and have a negative impact on the quality of life of patients. The consequences of these injuries affect their daily living and work activities. Approximately 3% of trauma patients worldwide are affected by these injuries which are commonly attributed to direct mechanical trauma and to surgical resection. Although the knowledge about the pathophysiology of these injuries has been progressing, they still present as a challenge to surgeons. The most severe type of nerve injury is known as neurotmesis, which in the most extreme case results in a completely transected nerve. This originates a nerve gap, with total interruption of the structural integrity of the support structure of the nerve. There are different strategies that can be used to repair a peripheral nerve injury, being that both surgical and non-surgical approaches can be implemented. Whenever tensionless suture across the nerve gap is not possible, surgeons resort to the gold-standard technique which is the use of autologous nerve grafts (autografts). To overcome the disadvantages associated to this technique, nerve guidance channels (NGCs) made of biomaterials have been viewed as an alternative approach. One of the biomaterials that has been considered as a preferable candidate for peripheral nerve regeneration is chitosan. **Methodology:** In order to understand how these chitosan NGCs mechanically behave after being implanted at an injury site, discrete models of the NGCs containing a segment of a peripheral nerve were built using numerical methods to analyze them such as the finite element method (FEM) and the radial point interpolation method (RPIM). The discrete models had variable geometrical parameters: the length of the NGC and its wall thickness. The elastic constants considered were the Poisson's coefficient and the Young's modulus. **Results and Discussion:** Stress and displacement fields were obtained in order to comprehend the structural response of the NGCs when subjected to external forces. With the obtained results concerning stress and displacement distributions, it was possible to understand how the NGCs mechanically behave and which structural features are more indicated for their use. **Conclusions:** Although many advances have been made in the past decades, there is still the need to evolve and improve the different approaches to repair injuries in the peripheral nervous system. Numerical methods such as FEM and RPIM can numerically simulate the mechanical behavior of the chitosan NGCs and help to understand how they can be mechanically improved.

**Keywords.** Peripheral nerve, Chitosan, Finite element method, Meshless methods.

## INTRODUCTION

### The repair of peripheral nerve injuries

Peripheral nerve injuries affect 3% of trauma patients worldwide and they frequently lead to unsatisfactory functional recovery and life-long disabilities, which might prevent patients from resuming their jobs (Chiono & Tonda-Turo, 2015; Faroni, Mobasser, Kingham, & Reid, 2015). Peripheral nerve injuries can occur after different traumatic events such as penetrating injury, crush, stretch, and ischemia (Ma, Fu, Jiang, & Zhang, 2016). Other causes also include gunshot wounds and vehicle accidents, being the latter considered by some studies as the main etiological factor (Babaei-Ghazani, Eftekharsadat, Samadirad, Mamaghany, & Abdollahian, 2017). It is known that younger patients as well as patients with more distal injuries fare better than older patients and more proximal injuries (Chhabra, Ahlawat, Belzberg, & Andreseik, 2014). In cases where the injury occurs, for example, in a nerve of the hand the restoration of function can increase the independence and the well-being of the patient (Magown, Shettar, Zhang, & Rafuse, 2015). The Seddon and Sunderland classifications are typically used to define the different types of injuries (Seddon, 1943; Sunderland, 1951). The most severe type of nerve injury is known as neurotmesis, which can result in the complete transection of the nerve originating a nerve gap. Consequently, the total interruption of the structural integrity of both the support structure of the nerve and its surrounding support structure occurs. This prevents a spontaneous recovery and leads to a complete motor, sensory and autonomic dysfunction

(Chiono & Tonda-Turo, 2015; Hainline, 2014; Houdek & Shin, 2015). The repair of nerve injuries has been attempted for several years, being that the first successful nerve tubulation was performed in 1882. Since then, major advances have been made, both in the understanding of the nerve regeneration process and the strategies implemented to treat each type of injury (Adigüzel et al., 2016; Dalamagkas, Tsintou, & Seifalian, 2016). After correct diagnosis of an injury, both surgical and non-surgical approaches can be implemented. The neurotmetic injuries require surgical intervention while other types of injuries can be treated by conservative methods (Lad, Nathan, Schubert, & Boakye, 2010). The surgical intervention to treat a nerve gap can be an epineurial repair where both nerve ends are sutured together without tension (Grinsell & Keating, 2014). Whenever tensionless suturing is not possible, surgeons resort to autografts which are considered the gold standard technique (Gu, Ding, Yang, & Liu, 2011; Nectow, Marra, & Kaplan, 2012). However, their use entails a series of drawbacks such as limited availability, morbidity at donor site, mismatch of donated nerves, loss of healthy nerve function and scar and neuroma formation (Ishikawa et al., 2009; Wu, Liu, Fang, Xiao, & Wan, 2017). One of the alternatives is the use of NGCs made of biomaterials, either natural or synthetic (Chiono & Tonda-Turo, 2015; Nectow et al., 2012; Zavan et al., 2008). Apart from the material, the architecture of the NGC can also differ. Some of the clinically available ones can have either a simple architecture or a more complex one, for they can be hollow tubes or they can have topographic cues (Grinsell & Keating, 2014). Chitosan is a natural and hydrophilic copolymer of D-glucosamine and N-acetyl-D-glucosamine units and it is obtained from full or partial N-deacetylation of chitin, which is the second most abundant polysaccharide found in nature (Gu et al., 2011). It has a set of biological properties that makes it an ideal biomaterial for a variety of applications. It is biocompatible and biodegradable, it is easily fabricated and modified and it has antibacterial properties (Li, Xiao, Zhang, Zhao, & Yang, 2017; Li et al., 2018).

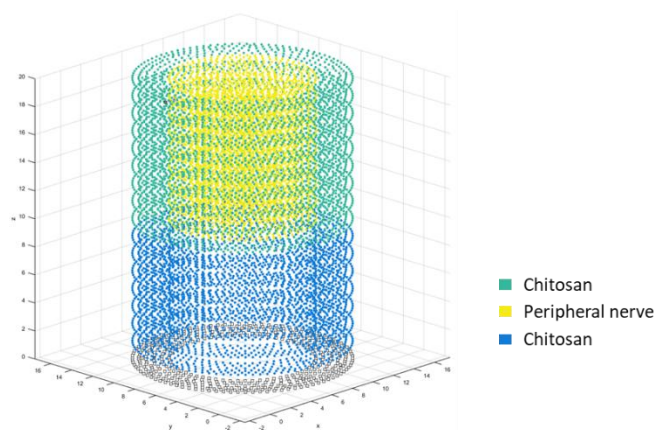
#### Numerical analysis

FEM is an important technology in the modelling and simulation of advanced mechanical engineering systems. As a numerical method, it seeks an approximated solution of the distribution of field variables in the problem domain, which would be difficult to obtain analytically (Fish & Belytschko, 2007; Liu & Quek, 2003). This analysis is obtained by dividing the problem domain in several elements with simple geometry to which known physical laws are applied (Liu & Quek, 2003). This numerical method can be used to create three-dimensional models of the peripheral nerve and the chitosan NGC to calculate tension values and deformations at specific points after applying loads (Behforootan, Chatzistergos, Naemi, & Chockalingam, 2016; Piao, Yang, Li, & Luo, 2015). Considering peripheral nerves, tissue mechanics and FEM analysis can be combined to explore their response when subjected to different stimuli (Giannessi, Stornelli, & Sergi, 2017). As an alternative to the FEM, new discretization methods called meshless methods have been developed. They allow to deal with large distortions problems, occurring in soft materials, and they can be combined with scanning techniques, which is an advantage comparing with FEM (Belinha, 2016; Wah, 2008; Yagawa & Yamada, 1996). Therefore, the goal of this work was to study the mechanical behavior of the chitosan NGCs with a segment of peripheral nerve inside of it. The models were analyzed considering both FEM and RPIM.

#### **METHODOLOGY**

The first step of this work was to construct the discrete models of the NGCs using the FEMAP software (student version). Two different geometric variables were considered: the length of

the channel (LC) and the thickness of the wall (TW). In the first case, LC varied between 15 and 35 mm while TW was always 1 mm. In the second case TW varied between 1 and 2.5 mm and LC was always 20 mm. In both cases the initial 10 mm of the channel were hollow. In all cases, the section of the NGC that is not hollow is filled with a segment of a peripheral nerve, as illustrated in Figure 1. The numerical analysis with FEM and RPIM was performed using FEMAS software (cmech.webs.com). The mechanical properties for the elasto-static analyses considered were the Young's modulus and the Poisson's coefficient. These constants were obtained from studies in the literature regarding pure, hydrated chitosan samples. Under the premise that the NGCs are subjected to external forces after implantation, a displacement of 1 mm was applied to one node of one of the NGC extremity while the opposite one was fixed. As advanced discretization techniques, FEM and RPIM were used for the numerical analysis. Stress fields were obtained to comprehend the structural response of the NGCs when subjected to external forces.



**Figure 1.** Representation of the discrete model of the chitosan NGC with the segment of nerve obtained from FEMAS software

## RESULTS

From the numerical analysis of the chitosan NGCs with FEM and RPIM, it was possible to obtain stress and displacement fields concerning both geometric variables. In Figures 2 and 3 are represented the total displacement of the NGC when LC and TW vary, respectively. As for Figures 4 and 5, they represent the stress fields and the corresponding equivalent von Mises stresses when LC and TW vary, respectively. The displacement fields represented in Figure 2 show that the total displacement at the top of the channel, where the displacement was applied, the values are higher and similar for both values of LC. However, when comparing FEM with RPIM, the displacement values are lower in the latter. Considering Figure 3, the displacement values are higher when TW is smaller, which is observed in both numerical models. Figure 4 shows that the distribution of stresses is mainly concentrated in the lower part of the NGC, as well as in the opposite part of the channel (not seen). On the contrary, the lowest values of stress are concentrated in the section of the tube that contains the segment of nerve. In Figure 5, the behavior is similar as in Figure 4. In both cases, the values of stress are higher when LC and TW are 20 mm and 1.5 mm, respectively.



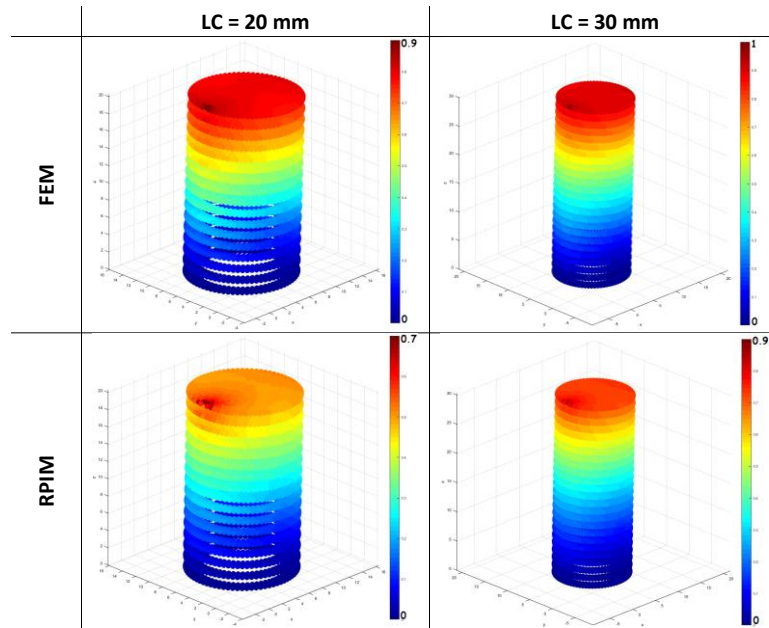


Figure 2. Representation of the total displacement in the model which geometric variable was the length of the channel

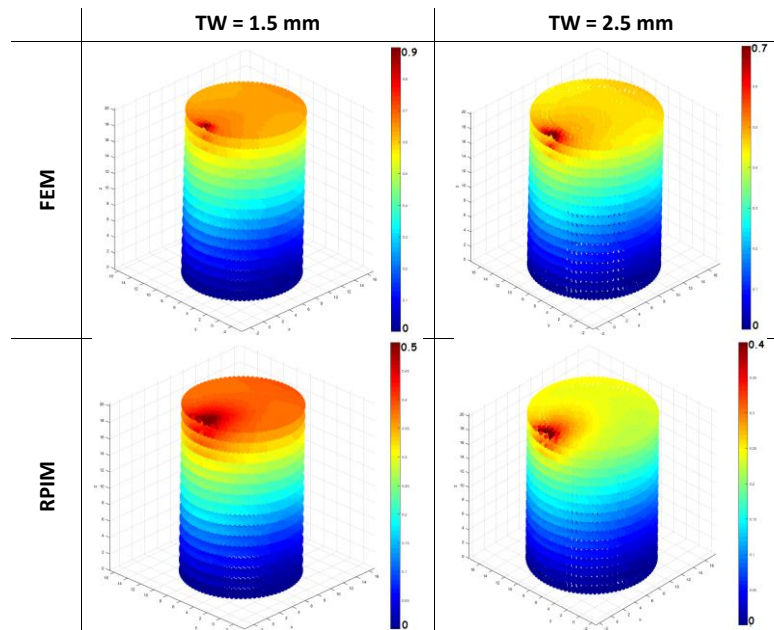


Figure 3. Representation of the total displacement in the model which geometric variable was the thickness of the wall

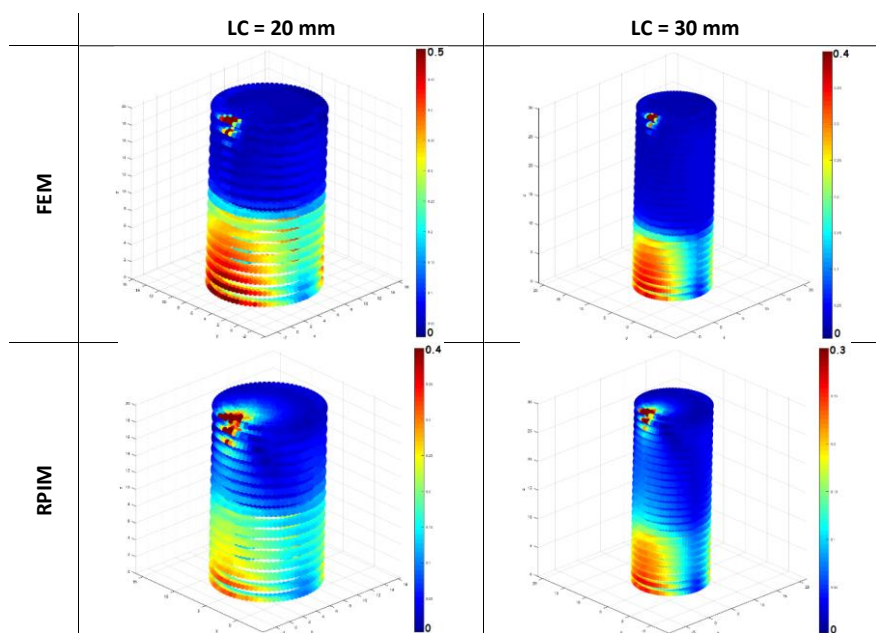


Figure 4. Distribution of the equivalent von Mises stresses in the model which geometric variable was the length of the channel

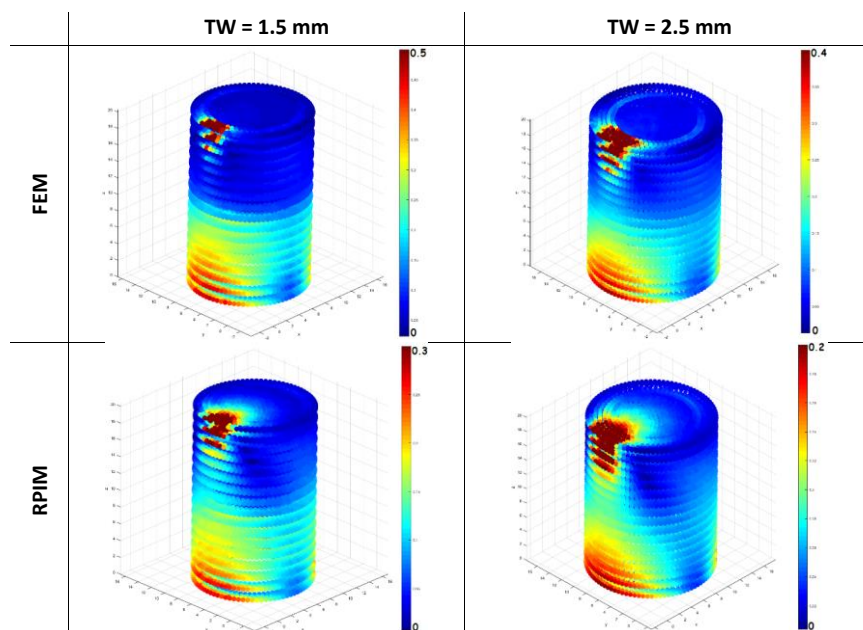


Figure 5. Distribution of the equivalent von Mises stresses in the model which geometric variable was the thickness of the wall

## DISCUSSION

In this study, discrete models of a chitosan NGC were constructed in order to understand how they would behave when subjected to an external load. Stress and displacement fields were obtained, and the numerical analysis was performed using FEM and RPIM. As it was mentioned in the results section, the displacement values are higher when TW is smaller, which is true for FEM and RPIM. This could mean that NGCs with a thicker wall would be more stable structures

and less susceptible to movement. In some extent, this is a desired feature of the NGCs since they must maintain their physical structure while the nerve regeneration process occurs. Concerning the distribution of stresses, the higher concentration in the lower part of the NGC is due to stretching and compressing in opposite parts of the structure. This is related to the direction in which the displacement is applied. Concerning the numerical methods, there are visible differences in the range of values of displacement and stress. A refinement of the mesh of the discrete models might be necessary in order to decrease these differences between both methods.

## CONCLUSIONS

Although many advances have been made in the past decades, there is still the need to evolve and improve the different approaches to repair injuries in the peripheral nervous system. Investigators have embarked in the mission of finding a strategy that allows surgeons to obtain good functional results in a consistent way. A promising one is the NGC made of chitosan used to bridge a nerve gap. With the help of numerical methods, such as FEM and RPIM, one can numerically simulate the mechanical behavior of NGCs made of chitosan and understand in what way they can be structurally improved. Ultimately this could lead to the development of a highly reliable and effective NGC and consequent repair of a peripheral nerve injury.

## Acknowledgments

The authors truly acknowledge the funding provided by Ministério da Ciência, Tecnologia e Ensino Superior – Fundação para a Ciência e a Tecnologia (Portugal), under project funding MIT-EXPL/ISF/0084/2017. Additionally, the authors gratefully acknowledge the funding of Project NORTE-01-0145-FEDER-000022 – SciTech – Science and Technology for Competitive and Sustainable Industries, co-financed by Programa Operacional Regional do Norte (NORTE2020), through Fundo Europeu de Desenvolvimento Regional (FEDER).

## References

- Adigüzel, E., Yaşar, E., Tecer, D., Güzelküçük, Ü., Taşkaynatan, M. A., Kesikburun, S., & Özgül, A. (2016). Peripheral nerve injuries: Long term follow-up results of rehabilitation. *Journal of Back and Musculoskeletal Rehabilitation*, 1, 1–5. <https://doi.org/10.3233/BMR-160681>
- Babaei-Ghazani, A., Eftekharsadat, B., Samadirad, B., Mamaghany, V., & Abdollahian, S. (2017). Traumatic lower extremity and lumbosacral peripheral nerve injuries in adults: Electrodiagnostic studies and patients symptoms. *Journal of Forensic and Legal Medicine*, 52, 89–92. <https://doi.org/10.1016/j.jflm.2017.08.010>
- Behforootan, S., Chatzistergos, P., Naemi, R., & Chockalingam, N. (2016). Finite element modelling of the foot for clinical application: A systematic review. *Medical Engineering & Physics*, 0, 1–11. <https://doi.org/10.1016/j.medengphy.2016.10.011>
- Belinha, J. (2016). *Meshless Methods in Biomechanics*. Porto: Springer.
- Chhabra, A., Ahlawat, S., Belzberg, A., & Andreseik, G. (2014). Peripheral nerve injury grading simplified on MR neurography: As referenced to Seddon and Sunderland classifications. *Indian Journal of Radiology and Imaging*, 24(3), 217–224. <https://doi.org/10.4103/0971-3026.137025>
- Chiono, V., & Tonda-Turo, C. (2015). Trends in the design of nerve guidance channels in peripheral nerve tissue engineering. *Progress in Neurobiology*, 131, 87–104. <https://doi.org/10.1016/j.pneurobio.2015.06.001>
- Dalamagkas, K., Tsintou, M., & Seifalian, A. (2016). Advances in peripheral nervous system regenerative therapeutic strategies: A biomaterials approach. *Materials Science and Engineering C*, 65, 425–432. <https://doi.org/10.1016/j.msec.2016.04.048>

- Faroni, A., Mobasser, S. A., Kingham, P. J., & Reid, A. J. (2015). Peripheral nerve regeneration: Experimental strategies and future perspectives. *Advanced Drug Delivery Reviews*, 82, 160–167. <https://doi.org/10.1016/j.addr.2014.11.010>
- Fish, J., & Belytschko, T. (2007). *A First Course in Finite Elements*. The Journal of Chemical Physics (Vol. 17). John Wiley & sons, Ltd. <https://doi.org/10.1063/1.1747391>
- Galanakos, S., Zoubos, A., Mourouzis, I., Ignatiadis, I., Bot, A., & Soucacos, P. (2013). Prognostic scoring system for peripheral nerve repair in the upper extremity. *Microsurgery*, 105–111. <https://doi.org/10.1002/micr.22000>
- Giannessi, E., Stornelli, M. R., & Sergi, P. N. (2017). A unified approach to model peripheral nerves across different animal species. *PeerJ*, 5, e4005. <https://doi.org/10.7717/peerj.4005>
- Grinsell, D., & Keating, C. P. (2014). Peripheral Nerve Reconstruction after Injury: A Review of Clinical and Experimental Therapies. *BioMed Research International*, 2014, 1–13. <https://doi.org/10.1155/2014/698256>
- Gu, X., Ding, F., Yang, Y., & Liu, J. (2011). Construction of tissue engineered nerve grafts and their application in peripheral nerve regeneration. *Progress in Neurobiology*, 93(2), 204–230. <https://doi.org/10.1016/j.pneurobio.2010.11.002>
- Hainline, B. W. (2014). Peripheral Nerve Injury in Sports. *CONTINUUM: Lifelong Learning in Neurology*, 20(6, Sports Neurology), 1605–1628. Retrieved from [http://journals.lww.com/continuum/Fulltext/2014/12000/Peripheral\\_Nerve\\_Injury\\_in\\_Sports.12.aspx](http://journals.lww.com/continuum/Fulltext/2014/12000/Peripheral_Nerve_Injury_in_Sports.12.aspx)
- Houdek, M. T., & Shin, A. Y. (2015). Management and Complications of Traumatic Peripheral Nerve Injuries. *Hand Clinics*, 31(2), 151–163. <https://doi.org/10.1016/j.hcl.2015.01.007>
- Ishikawa, N., Suzuki, Y., Dezawa, M., Kataoka, K., Ohta, M., Cho, H., & Ide, C. (2009). Peripheral nerve regeneration by transplantation of BMSC-derived Schwann cells as chitosan gel sponge scaffolds. *Journal of Biomedical Materials Research - Part A*, 89(4), 1118–1124. <https://doi.org/10.1002/jbm.a.32389>
- Lad, S. P., Nathan, J. K., Schubert, R. D., & Boakye, M. (2010). Trends in median, ulnar, radial, and brachiolexus nerve injuries in the United States. *Neurosurgery*, 66(5), 953–960. <https://doi.org/10.1227/01.NEU.0000368545.83463.91>
- Li, G., Xiao, Q., Zhang, L., Zhao, Y., & Yang, Y. (2017). Nerve growth factor loaded heparin/chitosan scaffolds for accelerating peripheral nerve regeneration. *Carbohydrate Polymers*, 171, 39–49. <https://doi.org/10.1016/j.carbpol.2017.05.006>
- Li, G., Xue, C., Wang, H., Yang, X., Zhao, Y., Zhang, L., & Yang, Y. (2018). Spatially featured porous chitosan conduits with micropatterned inner wall and seamless sidewall for bridging peripheral nerve regeneration. *Carbohydrate Polymers*, 194(December 2017), 225–235. <https://doi.org/10.1016/j.carbpol.2018.04.049>
- Liu, G. R., & Quek, S. S. (2003). *The finite element method - A practical course*. Butterworth Heinemann.
- Ma, M., Fu, Z., Jiang, B., & Zhang, P. (2016). Electrophysiological and imaging outcomes analysis in patients with peripheral nerve injury treated with biodegradable conduit small-gap (2 mm) tubulization: A 5-year follow-up. *International Journal of Clinical and Experimental Medicine*, 9(2), 3770–3774.
- Magown, P., Shettar, B., Zhang, Y., & Rafuse, V. F. (2015). Direct optical activation of skeletal muscle fibres efficiently controls muscle contraction and attenuates denervation atrophy. *Nature Communications*, 6, 1–9. <https://doi.org/10.1038/ncomms9506>
- Nectow, A. R., Marra, K. G., & Kaplan, D. L. (2012). Biomaterials for the development of peripheral nerve guidance conduits. *Tissue Engineering Part B: Reviews*, 18(1), 40–50. <https://doi.org/10.1089/ten.TEB.2011.0240>
- Piao, C.-D., Yang, K., Li, P., & Luo, M. (2015). Autologous nerve graft repair of different degrees of sciatic nerve defect: stress and displacement at the anastomosis in a three-dimensional finite element simulation model. *Neural Regeneration Research*, 10(5), 804–807. <https://doi.org/10.4103/1673-5374.156986>
- Seddon, H. J. (1943). Three types of nerve injury. *Brain*, 66(4), 237–288.
- Sunderland, S. (1951). A classification of peripheral nerve injuries producing loss of function. *Brain*, 74(4), 491–516.
- Wah, B. (2008). Finite element method. *Wiley Encyclopedia of Computer Science and Engineering*, 1–12. Retrieved from <http://onlinelibrary.wiley.com/doi/10.1002/9780470050118.ecse159/full>

Wu, H., Liu, J., Fang, Q., Xiao, B., & Wan, Y. (2017). Establishment of nerve growth factor gradients on aligned chitosan-poly lactide /alginate fibers for neural tissue engineering applications. *Colloids and Surfaces B: Biointerfaces*, 160, 598–609. <https://doi.org/10.1016/j.colsurfb.2017.10.017>

Yagawa, G., & Yamada, T. (1996). Free mesh method: A new meshless finite element method. *Computational Mechanics*, 18(5), 383–386. <https://doi.org/10.1007/BF00376134>

Zavan, B., Abatangelo, G., Mazzoleni, F., Bassetto, F., Cortivo, R., & Vindigni, V. (2008). New 3D hyaluronan-based scaffold for in vitro reconstruction of the rat sciatic nerve. *Neurological Research*, 30(2), 190–196. <https://doi.org/Doi10.1179/174313208x281082>

## Assessment of firefighters' occupational exposure to polycyclic aromatic hydrocarbons by biomonitoring

Marta Oliveira<sup>1</sup>, Klara Slezakova<sup>2</sup>, João Paulo Teixeira<sup>3</sup>, Adília Fernandes<sup>4</sup>, Maria Carmo Pereira<sup>5</sup>, Simone Morais<sup>6</sup>

<sup>1</sup>REQUIMTE-LAQV, School of Engineering, Polytechnic of Porto, PT (Marta.Oliveira@graq.isep.ipp.pt) ORCID 0000-0003-4150-0151, <sup>2</sup>LEPABE, Faculty of Engineering, University of Porto, PT (slezakok@fe.up.pt) ORCID 0000-0001-5265-4186, <sup>3</sup>EPIUnit, Institute of Public Health, University of Porto, PT (jpft12@gmail.com), <sup>4</sup>Polytechnic Institute of Bragança, PT (adilia@ipb.pt) ORCID 0000-0003-1658-4509, <sup>5</sup>LEPABE, Faculty of Engineering, University of Porto, PT (mcsp@fe.up.pt) ORCID 0000-0001-8505-3432, <sup>6</sup>REQUIMTE-LAQV, School of Engineering, Polytechnic of Porto, PT (sbm@isep.ipp.pt) ORCID 0000-0001-6433-5801

[https://doi.org/10.24840/978-972-752-260-6\\_0018-0021](https://doi.org/10.24840/978-972-752-260-6_0018-0021)

### Abstract

**Introduction:** Firefighters may suffer potential health risks due to the regular exposure to polycyclic aromatic hydrocarbons (PAHs) emitted from forest fires. This work determines the concentrations of the biomarker of exposure of PAHs, 1-hydroxypyrene, in the urine of firefighters recently exposed to fire emissions. **Methodology:** Urinary 1-hydroxypyrene was determined by solid-phase extraction followed by a liquid chromatographic analysis with fluorescence detection. **Results:** Urinary concentrations were 107% higher in firefighters that were recently involved in firefighting activities comparatively with the control Group (0.058 versus 0.028  $\mu\text{mol/mol}$  creatinine), respectively. Median concentrations of urinary 1-hydroxypyrene were below the benchmark level (0.5  $\mu\text{mol/mol}$  creatinine) proposed by American Conference of Governmental Industrial Hygienists. **Conclusions:** More studies including other PAH biomarkers of exposure and (bio)markers of early effect are necessary to better characterize firefighters' occupational exposure and to estimate the potential health risks.

**Keywords:** Occupational exposure, Firefighters, Biomarkers of exposure, PAH metabolites, 1-hydroxypyrene.

### INTRODUCTION

Portugal is among the southern European countries that present the highest danger for the occurrence of large forest fires and the risk is expected to continue increasing in the next decades (San-Miguel-Ayaz et al. 2018). Forest fires release large amounts of numerous hazardous pollutants to the atmosphere, which represent serious risks for the health of exposed fire combat forces and populations (Oliveira et al., 2015a, 2015b). Firefighting activities are among the most dangerous professions and are classified as possible carcinogen to humans by the International Agency for Research on Cancer and the US National Institute for Occupational Safety and Health (IARC 2010, NIOSH, 2007). Firefighters' occupational exposure has been associated with excess morbidity and mortality, with growing evidence supporting an association with all-cause of mortality, being cardiovascular disease the leading cause of death and a major cause of their morbidity (Oliveira et al., 2015a, 2015b). During fire combat activities, firefighters are heavily exposed to several hazardous pollutants, including particulate matter, nitrogen dioxide, carbon monoxide, volatile and semi-volatile organic compounds such as polycyclic aromatic hydrocarbons, PAHs (Gianniou et al., 2016; Oliveira et al., 2017). PAHs are ubiquitous hazardous pollutants with some compounds presenting toxic, mutagenic, endocrine disrupting and carcinogenic properties (IARC 2002, 2010; Oliveira et al., 2017; WHO, 2013). PAHs are also known to cause reproductive, developmental, cardiorespiratory, and immune toxic effects in humans (Oliveira et al., 2019). Firefighters are exposed to PAHs through the inhalation of gases, smoke and dusts released during fires, as well as through dermal exposure (Oliveira et al., 2015-PAHs). PAHs are absorbed into the human body and are distributed to the lipophilic tissues. Metabolization occurs via oxidative pathways in the liver to expedite their excretion from the human body in the form of glutathione, glucuronide, and sulphate conjugates through the urine, milk, and feces (Oliveira et al., 2019). However special attention has been given to urine since it is the easiest, cheapest, and less invasive matrix, which is particularly important for occupationally exposed groups. Regular exposure to health-relevant pollutants may induce

the generation of reactive species that will promote and/or aggravate pulmonary and cardiovascular inflammatory processes (Gianniou et al., 2016). Therefore, human biomonitoring is a precious tool to estimate the effective and total personal exposure to a specific pollutant, regardless of the route and duration of exposure (Oliveira et al., 2017, 2019). Among the available PAH biomarkers of exposure, 1-hydroxypyrene is the most widely used biological indicator of internal dose of PAHs exposure (Jongeneelen, 2014). This study determines firefighters' occupational exposure to PAHs, through the determination of urinary 1-hydroxypyrene, the PAHs biomarker of exposure, before and immediately after firefighting activities.

## METHODOLOGY

Forty-two firefighters serving at different fire stations situated in the district of Bragança (North of Portugal) fulfilled a questionnaire to collect data on their demographic characteristics (gender, age, and weight), and factors associated with PAH exposures including tobacco consumption, the most consumed meals (boiled, grilled, roasted), and recent exposure to fire emissions during the 2-3 days before sampling campaign. Participants signed a previously validated and approved informed consent (Ethic Committee of University of Porto; 12/CEUP/2015) and collected a spot urine sample at the end of their work-shift. Urine samples were collected in sterilized polycarbonate containers and frozen at  $-20^{\circ}\text{C}$  until analysis. Subjects were divided into two different groups: non-smoking and non-exposed to fire emissions (control group) and non-smoking and exposed to fires subjects. Urinary 1-hydroxypyrene was extracted and quantified according to Oliveira et al. (2017). Urinary extracts were analysed using a Shimadzu LC system (Shimadzu Corporation, Kyoto, Japan) equipped with a fluorescence detector in a C18 column (CC 150/4 Nucleosil 100–5C18PAH,  $150 \times 4.0$  mm;  $5 \mu\text{m}$  particle size; Macherey–Nagel, Duren, Germany) at room temperature ( $20 \pm 1^{\circ}\text{C}$ ). 1-hydroxypyrene was detected at its optimum excitation/emission wavelength pair (242/388 nm), Urinary levels of creatinine were determined by the Jaffe colorimetric method (Kanagasabapathy and Kumari, 2000) and used to normalize the concentrations of 1-hydroxypyrene. Analytical blanks and standards were analysed daily and regularly. Each analysis was performed at least in triplicate. Statistical analysis was done using SPSS (IBM SPSS Statistics 20) and Statistica software (v. 7, StatSoft Inc., USA). Levels of 1-hydroxypyrene were expressed as median values, compared through the nonparametric Mann-Whitney U test and statistical significance was defined as  $p \leq 0.05$ .

## RESULTS AND DISCUSSION

The firefighters that agreed to voluntarily participate in this study were all healthy (non-chronically diagnosed diseases) and non-smoking subjects with a mean age of 34 years (22-48 years). The time dedicated to firefighting activities within the 48 h prior the urine sampling collection varied between 1 to 8 hours. Urinary 1-hydroxypyrene was detected in all the exposed firefighters, and in 96% of the non-exposed individuals, thus reflecting its adequacy to evaluate occupational exposure to PAHs. Limited information is available concerning the elimination kinetics of urinary 1-hydroxypyrene, with half-life excretion rates ranging between 6-35 h after inhalation exposure (Brzezniński et al., 1997; Jongeneelen et al., 1990), 4-12 h after ingestion (Li et al., 2012), and reaches 13 h for dermal adsorption (Sobus et al., 2009; Viauet et al., 1995; Viau and Vyskocil, 1995). Urinary 1-hydroxypyrene concentrations were 107% higher in non-smoking subjects (median  $0.058 \mu\text{mol/mol}$  creatinine; range:  $0.019$ - $0.193 \mu\text{mol/mol}$  creatinine) that were directly involved in firefighting comparatively with non-smoking and non-exposed subjects

(median 0.028  $\mu\text{mol/mol}$  creatinine; range: 0.002-0.230  $\mu\text{mol/mol}$  creatinine). Studies regarding firefighters' occupational exposure to PAHs are limited. However, urinary levels of 1-hydroxypyrene in Portuguese firefighters were lower than the values reported by other authors for firefighters (Laitinen et al., 2010) and other occupationally exposed groups such as metallurgy, coke oven, and bitumen workers (Barbeau et al., 2014; Campo et al., 2012; Lotz et al., 2016). There are no guidelines for biomonitoring occupational exposure to PAHs in Europe. However, concentrations of 1-hydroxypyrene were always below the benchmark level of 0.5  $\mu\text{mol/mol}$  creatinine, proposed by the American Conference of Governmental Industrial Hygienists (ACGIH, 2010) and the no-biological effect level for occupational exposed workers (1.4  $\mu\text{mol/mol}$  creatinine) proposed by Jongeneelen (2014). Therefore, firefighters' occupational exposure to PAHs do not represent potential health hazards. Since firefighting is an intermittent occupation, firefighters' occupational exposure is directly related with the number of fire occurrences and the time spent with fire suppression. Therefore, firefighters' total internal dose of PAHs is expected to vary widely during the season of forest fires.

## CONCLUSIONS

This work characterized firefighters' occupational exposure to PAHs during their work shift after their active participation in firefighting activities. Firefighters that were actively involved in firefighting activities presented higher urinary concentrations of 1-hydroxypyrene than the subjects from the control group. More comprehensive studies during larger periods of time and including other PAH biomarkers of exposure are needed in a larger group of subjects to validate these findings.

## Acknowledgments

This work received financial support by projects UID/QUI/50006/2019 and UID/EQU/00511/2019 - Laboratory for Process Engineering, Environment, Biotechnology and Energy – LEPABE funded by national funds through FCT/MCTES. M. Oliveira thanks to FCT/MCTES for the CEEC- Individual 2017 Program Contract: CEECIND/03666/2017. Authors are thankful for the cooperation with Escola Superior de Saúde - Instituto Politécnico de Bragança and to all participants.

## References

- ACGIH. 2010. "Documentation for a Recommended BEI of Polycyclic Aromatic Hydrocarbons". American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, USA.
- Barbeau, D., R. Persoons, M. Marques, C. Herve, G. Laffitte-Rigaud, A. Maitre. 2014. "Relevance of urinary 3-hydroxybenzo(a) pyrene and 1-hydroxypyrene to assess exposure to carcinogenic polycyclic aromatic hydrocarbon mixtures in metallurgy workers". *Ann. Occup. Hyg.* 58: 579–590.
- Brzezniński, S., M. Jakubowski, B. Czerski, 1997. "Elimination of 1-hydroxypyrene after human volunteer exposure to polycyclic aromatic hydrocarbons". *Int. Arch. Occup. Environ. Health* 70: 257–260.
- Campo, L., L. Vimercati, A. Carrus, L. Bisceglia, A.C. Pesatori, P.A. Bertazzi, et al., 2012. "Environmental and biological monitoring of PAHs exposure in coke-oven workers at the Taranto plant compared to two groups from the general population of Apulia, Italy". *Med. Lav.* 103(5): 347-360.
- Gianniou, N., P. Katsaounou, E. Dima, C-E. Giannakopoulou, M. Kardara, V. Saltagianni, et al. 2016. "Prolonged occupational exposure leads to allergic airway sensitization and chronic airway and systemic inflammation in professional firefighters". *Resp. Med.* 118: 7-14. DOI: doi: 10.1016/j.rmed.2016.07.006.
- IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. 2002. "Some traditional herbal medicines, some mycotoxins, naphthalene and styrene". *IARC Monogr. Eval. Carcinog. Risks Hum.* 82: 1–556.



IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. 2010a. "Painting, Firefighting and Shiftwork". 98. International Agency for Research on Cancer, Lyon, France.

IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. 2010b. "Some non-heterocyclic polycyclic aromatic hydrocarbons and some related exposures". IARC Monogr. Eval. Carcinog. Risks Hum. 92: 1–853.

Jongeneelen, F.J. 2014. "A guidance value of 1-hydroxypyrene in urine in view of acceptable occupational exposure to polycyclic aromatic hydrocarbons". *Toxicol. Lett.* 231: 239–248.

Jongeneelen, F.J., F.E. Van Leeuwen, S. Oosterink, R.B. Anzion, L.F. van Der, R.P. Bos, et al. 1990. "Ambient and biological monitoring of cokeovenworkers: determinants of the internal dose of polycyclic aromatic hydrocarbons". *Br. J. Ind. Med.* 47: 454–461.

Kanagasabapathy, A.S., S. Kumari. 2000. "Guidelines on Standard Operating Procedures for Clinical Chemistry". World Health Organization, New Delhi, 25–28.

Laitinen, J., M. Mäkelä, J. Mikkola, I. Huttu. 2010. "Fire fighting trainers' exposure to carcinogenic agents in smoke diving simulators". *Toxicol. Lett.* 192: 61–65.

Li, Z., L. Romanoff, S. Bartell, E.N. Pittman, D.A. Trinidad, M. McClean, et al. 2012. "Excretion profiles and half-lives of ten urinary polycyclic aromatic hydrocarbon metabolites after dietary exposure". *Chem. Res. Toxicol.* 25: 1452–1461.

Lotz, A., B. Pesch, G. Dettbarn, M. Raulf, P. Welge, H-P. Ribs, et al. 2016. "Metabolites of the PAH diol epoxide pathway and other urinary biomarkers of phenanthrene and pyrene in workers with and without exposure to bitumen fumes". *Int. Arch. Occup. Environ. Health* 89: 1251–1267.

Oliveira, M., K. Slezakova, M.J. Alves, A. Fernandes, J.P. Teixeira, C. Delerue-Matos, et al.

2017. "Polycyclic aromatic hydrocarbons at fire stations: firefighters' exposure monitoring and biomonitoring, and assessment of the contribution to total internal dose". *J. Hazard. Mater.* 323: 184–194.

Oliveira, M., K. Slezakova, C. Delerue-Matos, M.C. Pereira, S. Morais. 2019. "Children environmental exposure to particulate matter and polycyclic aromatic hydrocarbons and biomonitoring in school environments: A review on indoor and outdoor exposure levels, major sources and health impacts". *Environment International* 124: 180–204.

Oliveira, M., K. Slezakova, C. Delerue-Matos, M.C. Pereira, S. Morais. 2017. "Firefighter's occupational exposure: Review on air pollutant levels and potential health effects". In: B. R. Gurjar, P. Kumar, and J N Govil (Eds) *Multi. Vol set on Environmental Science and Engineering (in 12 vols set), Vol. 3: Air and Noise Pollution*, Studium Press LLC, Houston, USA: 63–91.

Oliveira, M., K. Slezakova, C. Delerue-Matos, M.C. Pereira, S. Morais. 2015. "Polycyclic aromatic hydrocarbon emissions from forest fires: assessment of firefighters' exposure" In: Boone C (Ed). *Polycyclic Aromatic Hydrocarbons, Series: Environmental Science, Engineering and Technology*, Hauppauge, New York, USA: Nova Science Publishers, 59–94.

NIOSH. 2007. "NIOSH Pocket Guide to Chemical Hazards". U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health, Cincinnati, Ohio.

San-Miguel-Ayanz, J., T. Durrant, R. Boca, G. Libertà, A. Branco, D. de Rigo, et al. 2018. "Forest Fires in Europe, Middle East and North Africa 2017". EUR 29318 EN.

Sobus, J.R., M.D. McClean, R.F. Herrick, S. Waidyanatha, F. Onyemauwa, L.L. Kupper, et al. 2009. "Investigation of PAH biomarkers in the urine of workers exposed to hot asphalt". *Ann. Occup. Hyg.* 53: 551–560.

Viau, C., A. Vyskocil, 1995. "Patterns of 1-hydroxypyrene excretion in volunteers exposed to pyrene by the dermal route". *Sci. Total Environ.* 163: 187–190.

Viau, C., G. Carrier, A. Vyskocil, C. Dodd. 1995. "Urinary excretion kinetics of 1-hydroxypyrene in volunteers exposed to pyrene by the oral and dermal route". *Sci. Total Environ.* 163: 179–186.

WHO. 2013. "State of the Science of Endocrine Disrupting Chemicals 2012". United Nations Environment Programme and the World Health Organization, Geneva.

## Occupational exposure to dust in the mining industry context – a short review

J. Duarte<sup>1</sup>, Mário Vaz<sup>2</sup>, J. Torres Costa<sup>3</sup>, J. Santos Baptista<sup>4</sup>

<sup>1</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([jasduarte@fe.up.pt](mailto:jasduarte@fe.up.pt)) ORCID 0000-0002-5856-5317, <sup>2</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([gmavaz@fe.up.pt](mailto:gmavaz@fe.up.pt)) ORCID 0000-0002-6347-9608, <sup>3</sup>Faculty of Medicine, University of Porto, PT ([zecatoco@sapo.pt](mailto:zecatoco@sapo.pt)), <sup>4</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([jsbap@fe.up.pt](mailto:jsbap@fe.up.pt)) ORCID 0000-0002-8524-5503 [https://doi.org/10.24840/978-972-752-260-6\\_0022-0026](https://doi.org/10.24840/978-972-752-260-6_0022-0026)

### Abstract

**Introduction:** The exposure to breathable particulates pose a significant threat to human health globally. Several occupational activities can contribute to this problem, being mining one of them. The dust generated from mining activities such as drilling, crushing, loading, and unloading can reach the alveolar region of the lung, representing an occupational hazard. Miners are considered a high-risk group for respiratory morbidity and premature death since workers usually stay for an extended period of time on the mining front, for instance. The main objective of this short review was to characterise the occupational exposure to dust in the mining context, determining the main exposure values, occurrence circumstances, leading occupational diseases and their prevalence. **Methodology:** The PRISMA Statement guidelines were used in order to conduct the research. Engineering and health databases and journals were screened and the combinations of the following keywords were used in the first phase: “dust” and “particulate”, “open pit”, “open cast”, “quarry”, “mining industry”, “underground mining” and “extractive industry”. Later, the keywords “pneumoconiosis”, “silicosis” and “respiratory impairment” were added to the study. The prior defined exclusion criteria were date (only papers published after 2015 were considered), type of document (scientific papers and articles in press), type of source (journals and trade publications), language (English only) and a first screening was performed through the titles and abstracts in order to determine the scope. The included articles would have to be related to the main objective and reporting any outcome related to dust occupational exposure. **Results:** A total of 4,430 records were identified. After applying the exclusion criteria, only 17 remained. The references of the included studies were screened so to add other relevant articles, in the known snowballing technique process, where six more results were found. From those 23 final studies, 18 focused on dust collection processes and data, while five studied the occupational diseases related to the topic. **Discussion:** The interaction between the different variables – place, equipment, and activity – determine and influence the dust generation and spreading. However, the breathable dust concentration tends to be higher in the milling processes (crushing, concentration and pelletizing), than in the non-milling processes (mining, shop, and office or control rooms). The prevalence of diseases such as silicosis tend to increase with increasing age and may be highest among former smokers. The duration of exposure was also associated with an increase in the prevalence rate; for each additional year of silica exposure, this ratio increase was of about 4%. **Conclusions:** Mining activities are severely associated with the dust generation process. The overall objectives of the short review were achieved: the actual exposure values to dust were collected, and the circumstances in which it occurs were addressed. This study provided data to be considered in a dust mitigation process.

**Keywords:** Breathable particulates, Mining activity, Occupational disease, Short review.

### INTRODUCTION

Inorganic atmospheric particulates pose a significant risk to human health worldwide (Baur, Sanyal, & Abraham, 2019), where more than two million deaths are estimated to occur each year due to damage to the respiratory system (Kim, Kabir, & Kabir, 2015). However, according to the World Health Organization, no safe limit exists concerning community exposure to particulate pollution. This has several consequences for industries such as mining, since they are one of the primary sources of particulate emissions worldwide, especially for those countries where the open cut mining activity is abundant (Richardson, Rutherford, & Agranovski, 2019). Different mining activities can be linked to the occupational exposure to dust, cutting, drilling, crushing, loading and unloading (Andraos, Utembe, & Gulumian, 2018; Baur et al., 2019; Piras, Dentoni, Massacci, & Lowndes, 2014). Despite studies relate the exposure to the production phase of a mine, the non-production operations should, as well, be carefully studied. Miners are considered a high-risk group for premature death related to respiratory complications. Workers usually stay for an extended period of time on the mining front, so the dispersed dust particles in the respiratory area pose a significant problem (Xie, Cheng, Yu, & Sun, 2018). In the last decade, the incidence of mine dust related diseases has shown an increase (Mabila, Almberg, Friedman, & Cohen, 2018). This short review main objective was to characterise the

occupational dust exposure in the mining industry by determining the actual exposure values, the circumstances in which the exposure occurs, the occupational diseases associated with it and the prevalence of such diseases.

## METHODOLOGY

This short review was carried out following the Preferred Reporting of Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). In a first phase, the set of keywords defined was “dust” and “particulate”. These two were sequentially combined with “open pit”, “open cast”, “quarry”, “mining industry”, “underground mining” and “extractive industry”, separated by the Boolean operator “AND”. The main databases and journals within the scope of the review were selected (Current Contents, Scopus, Web of Science, SAGE, Academic Search Complete, ACS, DOAJ, Science Direct, Emerald, Inspec, IEEE Explore, Taylor and Francis, MEDLINE and PubMed). Only papers published between 2015 and 2019, written in English, with any applicable outcome, were considered. Then, from the selected studies, all references were screened in order to detect other relevant studies published before 2015, and new keywords were added to the research: “pneumoconiosis”, “silicosis” and “respiratory impairment”. Although the authors acknowledge these keywords do not reflect completely the occupational diseases that can be linked with the occupational exposure to dust, they focused in the results they found in a first research phase. Concerning the inclusion criteria, all type of studies analysing and collecting data regarding occupational exposure to dust will be considered. Any kind of outcome related to such exposure was also included.

## RESULTS

Following the proceedings from the PRISMA Statement (Moher et al., 2009), 4,430 records were identified, after which 3,099 papers were excluded by date. The second exclusion criteria were “type of paper” where 285 records were eliminated. The paper source was considered, leading to the rejection of 16 more papers. Manuscripts not written in English were disregarded, rejecting 72 texts. Duplicates (52 articles) and works without full-text access (after trying to reach the authors), three papers, were removed. After reading the title and the abstract, 868 articles did not comply with the proposed objective. After this process, 35 papers were considered eligible and were full-text screened. After the selection process (full-text reading) regarding the previously mentioned parameters, 17 articles were included for qualitative synthesis. After analysing their references by title and abstract, another 6 papers were added to the study. The main findings (23 studies) related to the subject can be divided into two types: dust-related data (18 studies) and health-related data (5 studies). Table 1 shows the main focus of each of the studies.

## CONCLUSIONS

Mining activities are intimately linked with the dust generation process, thus the importance of studying it, characterise it and, ultimately, minimize it. The overall objectives of the short review were achieved: the actual exposure values to dust were collected, and the circumstances in which it occurs were addressed. The breathable dust concentrations are usually higher in the milling processes such as crushing, concentration and pelletizing. Drilling was also found to be one of the activities with higher risk. A lot of diseases have been associated with occupational exposure to dust over time. This short review focused in five papers reporting silicosis, obstructive lung disease, coal workers pneumoconiosis and respiratory impairment, not because

they stand as the only concerns, but because they were the only found works when applying the investigation criteria. The prevalence of these diseases also increases with increasing age. Relating technical issues with health, the absence of adequate ventilation in the underground, and the use of dry drilling was associated with an increase in the prevalence rate of silicosis.

**Table 1.** Studies' related data

Author (year)	Commodity (and type of mine)	Study focus
Churchyard et al. (2004)	Gold (not mentioned)	Health
Mukherjee et al. (2005)	Coal (surface and underground)	Activity, worker
Reed and Organiscak (2005)	Stone and coal (surface)	Equipment
Hayumbu et al. (2008)	Copper (underground)	Place
Onder & Yigit (2009)	Coal (surface)	Activity
Aydin (2010)	Coal (underground)	Health
Prostański (2015)	Coal (underground)	Place
Lashgari & Kecojevic (2016)	Coal (surface)	Equipment
Lebecki et al. (2016)	Coal (underground)	Activity
Rabeyi et al. (2016)	Gold (surface and underground)	Place
Hwang et al. (2017)	Taconite (not mentioned)	Activity, worker
Johann-Essex et al. (2017)	Coal (underground)	Not specified
Pandey et al. (2017)	Coal (underground)	Activity
Souza et al. (2017)	Amethyst (underground)	Health
Brodny & Tutak (2018)	Coal (underground)	Place, activity
Jiang et al. (2018)	Not applicable (laboratory)	Activity
Mabila et al. (2018)	Not mentioned	Health
Prakash et al. (2018)	Coal (underground)	Activity
Rusibamayila et al. (2018)	Gold (surface and underground)	Health
Sairanen & Rinne (2018)	Aggregates (surface)	Equipment, activity
Sairanen & Selonen (2018)	Aggregates (surface)	Equipment
Wanjun & Qingxiang (2018)	Coal (surface)	Activity, equipment
Richardson et al. (2019)	Coal (surface)	Activity

## References

- Andraos, C., Utembe, W., & Gulumian, M. (2018). Exceedance of environmental exposure limits to crystalline silica in communities surrounding gold mine tailings storage facilities in South Africa. *Science of the Total Environment*, 619–620, 504–516. <https://doi.org/10.1016/j.scitotenv.2017.11.135>
- Aydin, H. (2010). Evaluation of the risk of coal workers pneumoconiosis ( CWP ): A case study for the Turkish hardcoal mining. *Scientific Research and Essays*, 5(21), 3289–3297.
- Baur, X., Sanyal, S., & Abraham, J. L. (2019). Mixed-dust pneumoconiosis: Review of diagnostic and classification problems with presentation of a work-related case. *Science of the Total Environment*, 652, 413–421. <https://doi.org/10.1016/j.scitotenv.2018.10.083>
- Brodny, J., & Tutak, M. (2018). Exposure to harmful dusts on fully powered longwall coal mines in Poland. *International Journal of Environmental Research and Public Health*, 15(9). <https://doi.org/10.3390/ijerph15091846>

- Churchyard, G. J., Ehrlich, R., TeWaterNaude, J. M., Pemba, L., Dekker, K., Vermeijs, M., ... Myers, J. (2004). Silicosis prevalence and exposure-response relations in South African goldminers. *Occupational and Environmental Medicine*, *61*(10), 811–816. <https://doi.org/10.1136/oem.2003.010967>
- Hayumbu, P., Robins, T. G., & Key-Schwartz, R. (2008). Cross-sectional silica exposure measurements at two Zambian copper mines of Nkana and Mufulira. *International Journal of Environmental Research and Public Health*, *5*(2), 86–90. <https://doi.org/10.3390/ijerph2008050010>
- Hwang, J., Ramachandran, G., Raynor, P. C., Alexander, B. H., & Mandel, J. H. (2017). A comprehensive assessment of exposures to respirable dust and silica in the taconite mining industry. *Journal of Occupational and Environmental Hygiene*, *14*(5), 377–388. <https://doi.org/10.1080/15459624.2016.1263392>
- Jiang, H., Luo, Y., & McQuerrey, J. (2018). Experimental study on effects of drilling parameters on respirable dust production during roof bolting operations. *J. Occup. Environ. Hyg. (UK)*, *15*(2), 143–151. Retrieved from <http://dx.doi.org/10.1080/15459624.2017.1395960>
- Johann-Essex, V., Keles, C., Rezaee, M., Scaggs-Witte, M., & Sarver, E. (2017). Respirable coal mine dust characteristics in samples collected in central and northern Appalachia. *Int. J. Coal Geol. (Netherlands)*, *182*, 85–93. Retrieved from <http://dx.doi.org/10.1016/j.coal.2017.09.010>
- Kim, K.-H., Kabir, E., & Kabir, S. (2015). A review on the human health impact of airborne particulate matter. *Science Direct*, *74*, 136–143. <https://doi.org/10.1016/j.envint.2014.10.005>
- Lashgari, A., & Kecojevic, V. (2016). Comparative analysis of dust emission of digging and loading equipment in surface coal mining. *International Journal of Mining, Reclamation and Environment*, *30*(3), 181–196. <https://doi.org/10.1080/17480930.2015.1028516>
- Lebecki, K., Małachowski, M., & Sołtysiak, T. (2016). Continuous dust monitoring in headings in underground coal mines. *Journal of Sustainable Mining*, *15*(4), 125–132. <https://doi.org/10.1016/j.jsm.2017.01.001>
- Mabila, S. L., Almqvist, K. S., Friedman, L., & Cohen, R. (2018). High exposure mining occupations are associated with obstructive lung disease, National Health Interview Survey (NHIS), 2006-2015. *American Journal of Industrial Medicine*, *61*(9), 715–724. <https://doi.org/10.1002/ajim.22890>
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., Altman, D., Antes, G., ... Tugwell, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, *6*(7). <https://doi.org/10.1371/journal.pmed.1000097>
- Mukherjee, A. K., Bhattacharya, S. K., & Saiyed, H. N. (2005). Assessment of Respirable Dust and its Free Silica Contents in Different Indian Coal mines. *Industrial Health*, *43*(2), 277–284. <https://doi.org/10.2486/indhealth.43.277>
- Onder, M., & Yigit, E. (2009). Assessment of respirable dust exposures in an opencast coal mine. *Environmental Monitoring and Assessment*, *152*(1–4), 393–401. <https://doi.org/10.1007/s10661-008-0324-4>
- Pandey, J. K., Agarwal, D., Gorain, S., Dubey, R. K., Vishwakarma, M. K., Mishra, K. K., & Pal, A. K. (2017). Characterisation of respirable dust exposure of different category of workers in Jharia Coalfields. *Arab. J. Geosci. (Germany)*, *10*(7), 183 (10 pp.). Retrieved from <http://dx.doi.org/10.1007/s12517-017-2974-4>
- Piras, L., Dentoni, V., Massacci, G., & Lowndes, I. S. (2014). Dust dispersion from haul roads in complex terrain: the case of a mineral reclamation site located in Sardinia (Italy). *International Journal of Mining, Reclamation and Environment*, *28*(5), 323–341. <https://doi.org/10.1080/17480930.2014.884269>
- Prakash, B. B., Kecojevic, V., & Lashgari, A. (2018). Analysis of dust emission at coal train loading facility. *Int. J. Min. Reclam. Environ. (UK)*, *32*(1), 56–74. Retrieved from <http://dx.doi.org/10.1080/17480930.2016.1253138>
- Prostański, D. (2015). Experimental study of coal dust deposition in mine workings with the use of empirical models. *Journal of Sustainable Mining*, *14*(2), 108–114. <https://doi.org/10.1016/j.jsm.2015.08.015>

- Rabeiy, R. E., ElTahlawi, M. R., & Boghdady, G. Y. (2016). Occupational health hazards in the Sukari Gold Mine, Egypt. *Journal of African Earth Sciences*. <https://doi.org/10.1016/j.jafrearsci.2017.04.023>
- Reed, W. R., & Organiscak, J. A. (2005). Evaluation of dust exposure to truck drivers following the lead haul truck. *SME Annual Meeting*, 1–9. <https://doi.org/10.1016/j.vhri.2015.10.010>
- Richardson, C., Rutherford, S., & Agranovski, I. E. (2019). Open cut black coal mining: Empirical verification of PM2.5 air emission estimation techniques. *Atmospheric Research*, 216, 151–159. <https://doi.org/10.1016/j.atmosres.2018.10.008>
- Rusibamayila, M., Meshi, E., & Mamuya, S. (2018). Respiratory impairment and personal respirable dust exposure among the underground and open cast gold Miners in Tanzania. *Annals of Global Health*, 84(3), 419–428. <https://doi.org/10.1002/14651858.CD004508.pub3>
- Sairanen, M., & Rinne, M. (2018). Dust emission from crushing of hard rock aggregates. *Atmospheric Pollution Research*. <https://doi.org/https://doi.org/10.1016/j.apr.2018.11.007>
- Sairanen, M., & Selonen, O. (2018). Dust formed during drilling in natural stone quarries. *Bulletin of Engineering Geology and the Environment*, 77(3), 1249–1262. <https://doi.org/10.1007/s10064-017-1016-5>
- Souza, T. P., Watte, G., Gusso, A. M., Souza, R., Moreira, J. da S., & Knorst, M. M. (2017). Silicosis prevalence and risk factors in semi-precious stone mining in Brazil. *American Journal of Industrial Medicine*, 60(6), 529–536. <https://doi.org/10.1002/ajim.22719>
- Wanjun, T., & Qingxiang, C. (2018). Dust distribution in open-pit mines based on monitoring data and fluent simulation. *Environmental Monitoring and Assessment*, 190(11). <https://doi.org/10.1007/s10661-018-7004-9>
- Xie, Y., Cheng, W., Yu, H., & Sun, B. (2018). Microscale dispersion behaviors of dust particles during coal cutting at large-height mining face. *Environmental Science and Pollution Research*, 25(27), 27141–27154. <https://doi.org/10.1007/s11356-018-2735-2>

## OWAS method analysis applied to a slaughterhouse company

Ana Sophia Rosado<sup>1</sup>, Carolina Garreto<sup>2</sup>, J. Duarte<sup>3</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT (anasgmr@yahoo.com.br) ORCID: 0000-0002-4935-4171, <sup>2</sup>Faculty of Engineering, University of Porto, PT (carolgarreto@gmail.com) ORCID 0000-0001-7138-7714, <sup>3</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (jasduarte@fe.up.pt) ORCID 0000-0002-5856-5317  
[https://doi.org/10.24840/978-972-752-260-6\\_0027-0033](https://doi.org/10.24840/978-972-752-260-6_0027-0033)

### Abstract

**Introduction:** The Industrial Revolution was a milestone in world development, but as every innovative process, it has also brought adverse situations, especially to the health of the worker. The beginning of the industrial process was marked by the repetitiveness of movements and monotony at work. Subsequently, the automation developed and modified the form of production. However, despite the improvements in the industry, the same effort is still noted, characterized by the exhaustive repetition of movements, the requirement of the same muscular group daily and monotony, factors that cause stress, musculoskeletal injuries and occupational accidents. The objective of this research was to assess the index of workers with musculoskeletal injuries. **Methodology:** The study was developed in two sectors of a slaughterhouse located in the south of Brazil: chicken's wing cut sector and platform sector. The observation, in situ, allowed the ergonomic analysis through the Ovako Working Posture Analyzing System (OWAS) method to assess the ergonomic risks of the postures based on the position of the back, arms, and legs of the workers. Time and methods were analyzed, as well as the medical records of all workers, which were registered and assessed. For the statistical analysis, workers were divided into a) uptime, b) workers who had already exercised demanding work activity of physical exertion and/or repetition of movements and the form of removal (with medical low or without medical low) and, c) by gender. **Results and discussion:** Through the use of the OWAS method, it was verified that workers from both sectors are not exposed to ergonomic risk. Therefore, hypothetically, they would not be subjected to musculoskeletal injuries. These results were then compared with the medical records and there was disagreement between the result of the ergonomic method and the number of injured workers. Women were the most affected by the musculoskeletal injuries. Regarding the male universe, the majority of mean suffering from musculoskeletal injuries were those who had previously worked with the activities that required force and/or repetition of movements. **Conclusions:** It was determined that the index of injured workers were 25% of women in the wing cut, and 17% of men in the platform sector, which was not coherent with the application of the Ovako Working Posture Analyzing System method. It is believed the main reason is that the method does not consider the movements repetitiveness which characterises the activity. Therefore, it would be helpful for the analysis that the ergonomic study is performed using several tools, so that the result is reliable, given the dissonances that may exist between methods and means of analysis.

**Keywords.** Occupational Disease, Ergonomics, Fatigue, OWAS Method, Osteomuscular Injury.

### INTRODUCTION

The industrial revolution was marked by the exchange of the use of tools by machines. What characterizes the industrial revolution is not the machine itself, but the machinery in the industry. The automation in the industry allowed to reduce costs, to increase production and, at the same time, the profit (Teixeira & Souza, 2013). Apart from the production and capital, the search for the profitability left, on many occasions, the worker unattended regarding well-being and safety, because of the requirement to increase and improve the production (Cohn, Hirano, Karsch, & Sato, 1985). Taylorism and Fordism, with the use of innovative technologies, are the first models of industrial production but require exhaustive repetition of movements, that may result in the excessive effort and severe fatigue, leading to the emergence of musculoskeletal injuries (Couto, 2014). These production models are still in use, thus the importance of the ergonomics study in the working environment. The work-related musculoskeletal disorders (WMSD) is a reality experienced by workers from different areas and are a result of repetitive efforts and inadequate ergonomic conditions (Lourinho, Vieira, Almeida, Quemelo, & Negreiros, 2012). Musculoskeletal injuries result from the professional risk factors such as repetitiveness, overload and/or adopted postures during work (Uva, Carnide, Serranheira, Miranda, & Lopes, 2008). When the disease result from work, they are called occupational diseases, which are defined as "the effect of continued work, causing a reversible reduction of the organism's capacity, being caused by a set of factors (Iida, 2005). The working conditions in two sectors of a slaughterhouse company in Brazil were analysed, where the work is repetitive and utterly

demanding on the upper limbs throughout the day. The study objective was to assess the index of workers with musculoskeletal injuries.

## METHODOLOGY

The study was developed in two sectors of a slaughterhouse located in the south of Brazil: chicken's wing cut sector and platform sector. The company has two production shifts: one from 04:00h to 13:30h and one from 14:00h to 23:30h, with three pauses of 00:20h and one pause of 01:00h. The resting periods are destined for feeding and for muscle rest, in order to avoid muscular fatigue. The analysis was developed by observation *in situ*, registered by photographs and filming. Subsequently, the *Ovako Working Posture Analyzing System* (OWAS) method was used to analyse the registered observations (Iida, 1990). The method provides scores in ascending order of severity, according to the value assigned to the back and arms from 1 to 3, and the legs score from 1 to 7. The strength performed by the worker was also analysed. Therefore, to each posture assumed by a worker, it was attributed a 4-digit code that depended on the classification within the previous postures for each part of the body, and the respective load (Gómez-Galán, Pérez-Alonso, Callejón-Ferre, & López-Martínez, 2017). After analyzing the body and the strength, the general table of scores was used. The intersection of the results obtained generated a final numerical risk result from 1 to 4, being 1 considered a "normal posture" and 4 a "posture that requires immediate attention". Regarding the prevalence of occupational diseases, the medical records of all workers in the sector were assessed, and especially attention was provided to the following information: sex, age, admission (uptime), medical leave, number of absence days provided by social security, International Code of Diseases (ICD), social security benefits, previous function, period worked. For the statistics of the occupational diseases through the assessment of the medical documents, workers were separated into the following categories:

- ✓ Workers with less than two working years at the company;
- ✓ Workers with two to five working years at the company;
- ✓ Workers over five working years at the company.

## RESULTS AND DISCUSSION

In the platform sector, the product (chickens) arrives in boxes, which are discharged by two employees and placed on a treadmill. The treadmill transports the products to the platform sector, where the chicken is hung. As the boxes go through the treadmill, the platform employees hang the product (one by one) on hooks located just above them. To hang the chicken, which is approximately 2.8 kg, the worker lifts both arms up or above the shoulders. In the wing cut sector, the products arrive hanging on the hooks. The hooks are located approximately at the height of the workers' centre of gravity (abdomen region). The worker cut the wings using his arms (at the height of the abdomen), without needing to lift them up or above the shoulders. In both sectors, employees are positioned in front of the products, with no back rotation. As for the position of the upper limbs, the arms move up and down (in the platform), forward and backward (in the wing cut), continuously. The average slaughter is 50,000 birds per shift. There are 7,500 products per hour, which equals 125 products per minute.

- ✓ Platform: there are 9 employees in the sector. The pace of work is 13.9 products per employee every minute. The population of workers in the sector is 100% male. The



weight of each product is approximately 2.8kg. Three technical actions are counted in each cycle: pick up-rotate-position, which equals 41.7 technical actions per minute;

- ✓ Wing cutting: there are 20 employees in the sector. The pace of work is 12.5 products per employee every minute. Each product has 2 wings, which equals 25 cuts per minute per employee. The population is 66.7% female and 33.3% male. The weight and dimensions of the knife used are negligible for this specific case. Two technical actions are counted in each cycle: catch the wing-cut, which equals 25 x 2 (two wings) technical actions per minute.

The images below exemplify the activity: Figure 1 shows a similar production line (Nunes, 2008) and in Figure 2 (Takeda, Oliveira, & Xavier, 2009) can be observed the knife on the right hand of the worker. Disclosure of industry images has not been authorized by the industry.



Figure 1. Platform sector



Figure 2. Cut wing sector

The scores obtained using the OWAS method are presented in Table 1 and Table 2, for the platform sector and wing cutting sector, respectively. According to the obtained results by the ergonomic analysis (OWAS), workers from both sectors are not exposed to ergonomic risk. So, hypothetically, they would not be subjected to musculoskeletal injuries. To confirm the obtained results, the medical records of all workers registered in the sectors (cutting the wing of the chicken and platform) were analyzed. It was found that there were sick leaves due to musculoskeletal injuries in both sectors. Given the information, the clearings were divided into:

- ✓ Workers with a sick leave without social security clearance (period less than 15 days);
- ✓ With social security clearance (period exceeding 15 days);
- ✓ Workers who, before joining the company, had already performed activities demanding of upper limbs (harmful function).

**Table 2.** OWAS method results in platform sector

<b>Task: Platform</b>		
<b>Body part</b>	<b>Position</b>	<b>Pontuation</b>
<b>Back posture</b>	Upright	1
<b>Arms</b>	Two above shoulder joint	3
<b>Legs</b>	Standing with one leg upright	2
<b>ANALYSIS RESULT</b>		1

**Table 3.** OWAS method results in wing cutting sector

<b>Task: Wing cutting</b>		
<b>Body part</b>	<b>Position</b>	<b>Pontuation</b>
<b>Back posture</b>	Upright	1
<b>Arms</b>	One above shoulder joint	2
<b>Legs</b>	Standing with one leg upright	2
<b>ANALYSIS RESULT</b>		1

Figures 3, 4 and 5 display graphs of the statistical of musculoskeletal injuries in men and women registered in both sectors. It was verified that the results obtained by the ergonomic analysis method (OWAS) diverge from the reality experienced by the workers since the method does not indicate postural risks. However, musculoskeletal injuries that affect workers are aggravated by repetitive activity. It is believed that the lesions are the result of upper limb overload, considering the extremely repetitive activity. The repetition of movements is daily and throughout the entire working day. Repetitive work is one of the causes of muscular fatigue (Iida, 1990). The ergonomic analysis by the OWAS method allowed to conclude that the posture adopted by the worker was not harmful (risk 1-normal posture). The analysis of medical records, on the other hand, showed that a significant percentage of workers suffer or suffered from musculoskeletal injuries. It can be said that the work is repetitive and exhaustive, factors not considered by the OWAS method. Musculoskeletal disorders occurred in both sectors. The most noted incidences occurred:

- ✓ 25% of women in the wing cut (with social security clearance);
- ✓ 17% of men in the platform sector (who had already exercised harmful activities, especially for the upper limbs);
- ✓ 8% of women in the wing cut (without social security clearance).

It is important to emphasize some differences in both sectors:

- ✓ On the platform sector, the worker does the abduction of upper limbs, the elevation of load and 41 technical actions per minute;
- ✓ On the wing-cut, the worker performs 50 technical actions per minute. However, he does not perform abduction of upper limbs or elevation of loads.

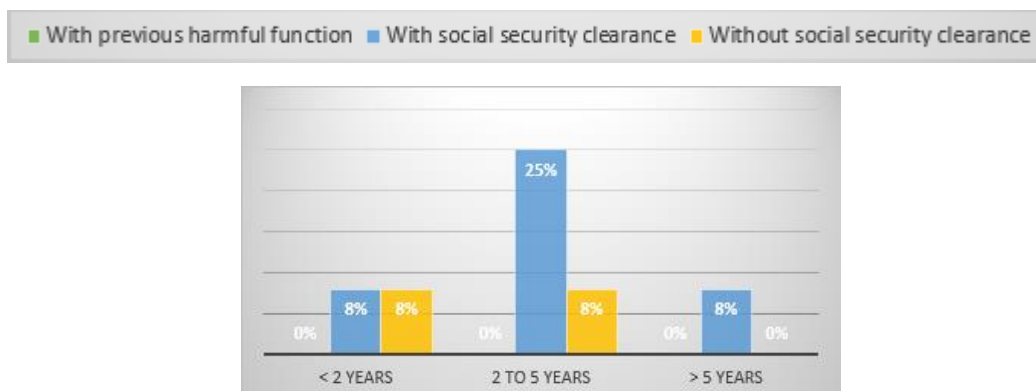


Figure 3. Women with social security (wing cut)

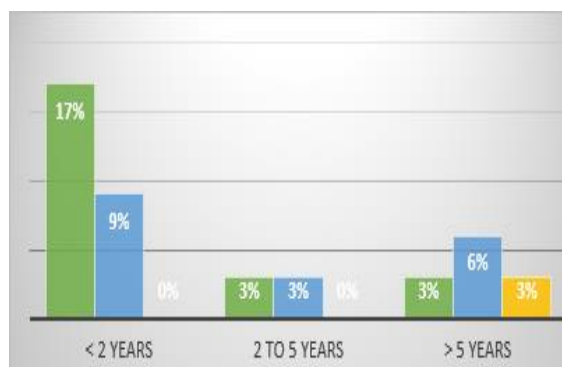


Figure 4. Men (platform sector)

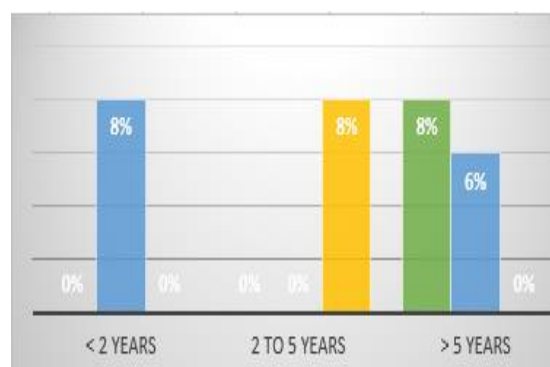


Figure 5. Women without social security (wing cut)

Whereas, although the worker in the wing cutting exercises more technical actions per minute, the activity is less painful. Still, women were the most affected by musculoskeletal injuries. However, in the male universe, who most suffered from musculoskeletal injuries were those who had previously worked with the activities that required force and/or repetition of movements. It can be said that musculoskeletal injuries are chronic because most of the work-related musculoskeletal injuries develop over time (EU-OSHA, 2018). The same European document reports that such injuries often result from the combination of several factors, including the movement of loads and repetitive or repetitive movements, cases that fall into reality under analysis. On the other hand, men who perform the less painful activity and did not have realized demanding activities were injured less, although there were injuries to this population. According to Cezar-vaz, *et al* (2012) these diseases develop due to excessive overloads of the muscles, exposed to repetitive movements and localized efforts. They are usually originated by repetitive movements that overcome the resistance capacity of the components of the locomotor system, such as bones, tendons, ligaments and muscles, often associated. The repetitive movements is evidently a demanding activity that deserves attention. It should be noted that the company analyzed performs three pauses of twenty minutes along the journey beyond the lunch/dinner hours, in order to allow the rest of the member required. However, the measure adopted is not sufficient to neutralize the injuries. Measures of avoiding or reducing the cadence of repetitive movements can be studied, as well as activity rotation is important.

## CONCLUSIONS

The analysis by *Ovako Working Posture Analyzing System* method considered that the postures adopted are ergonomically normal, without risk to the workers' musculoskeletal structure. However, the medical records verification has demonstrated that in both sectors there are incidence of musculoskeletal injuries, being more clear in the female population (25% of women in the wing cut), followed by the male population (17% of men in the platform sector) who had already worked on demanding activities and/or with the repetitiveness of movements. It can be said that medical records reflect the reality experienced by the workers. The assessment of medical records made it clear that the employees who have previously engaged in harmful activities are more susceptible to injury because the requirement of a certain muscle group for a continuous period tends to be harmful to the physical structure. Thus, the rotation of activities, avoiding monotony and muscular fatigue, is extremely important. However, knowing that the human body is not an exact machine, it is important to do analyse using other complementary methods. Therefore, the analysis of medical records proved to be important. Musculoskeletal injuries occurred mainly due to the exhaustive repetition of movements of the upper limbs, a fact not considered in the analysis of through the *Ovako Working Posture Analyzing System* method.

## References

- CANÊDO, Letícia Bicalho. A Revolução Industrial – Discutindo a História. Editora Atual, 23ª ed., 2010.
- COHN, A.; HIRANO, S.; KARSCH, U. S.; SATO, A.K. Acidentes do trabalho – uma forma de violência. Editora Brasiliense S.A., 1985.
- COUTO, H. A. Ergonomia do corpo e do cérebro no trabalho. Editora Ergo, 2014.
- Direcção-Geral da Saúde. Lesões Musculoesqueléticas Relacionadas com o Trabalho Guia de Orientação para a Prevenção.
- IIDA, Itiro. Ergonomia: Projeto e Produção. São Paulo-SP. Ed. Edgard Blucher Ltda. 1990.
- LOURINHO, Mayra Guasti; NEGREIROS, Glenda Rocha; ALMEIDA, Larissa Brentini de; VIEIRA, Edgar Ramos; QUERNELO, Paulo Roberto Veiga. Riscos de lesão musculoesquelética em diferentes setores de uma empresa calçadista. Fisioterapia e Pesquisa, São Paulo, v18, n.3, p.252-7m jul/set.2011.
- MÁSCULO, F. S.; VIDAL, M. C. Ergonomia: trabalho adequado e eficiente. 5ª tiragem. Elsevier Editora Ltda, 2011.
- MENDES, René. Medicina do Trabalho – Doenças profissionais. Sarvier S.A. Editora de Livros Médicos, 1980.
- OLIVEIRA, Elke. Força: Mulher x Homem. Data: 04/04/2003. [http://www.gease.pro.br/artigo\\_visualizar.php?id=64](http://www.gease.pro.br/artigo_visualizar.php?id=64). Data da pesquisa: 21/04/2017.
- SILVA, Danilo Corrêa; SILVA, João Carlos Riccô Plácido; CARNEIRO, Luciane do Prado; SILVA, José Carlos Plácido da; PASCHOARELLI, Luis Carlos. Contribuições Científicas de Bernard Forest de Bélidor para o Estudo e a Organização do Trabalho. Ed. Unesp. 2010.
- Cezar-vaz, M. R., Fernanda, J., Soares, D. S., & Regina, M. (2012). Prevalência de doenças musculoesqueléticas entre trabalhadores portuários avulsos, 20(2), 1–8. Retrieved from [http://www.scielo.br/pdf/rlae/v20n2/pt\\_05.pdf](http://www.scielo.br/pdf/rlae/v20n2/pt_05.pdf)
- Cohn, A., Hirano, S., Karsch, U. S., & Sato, A. K. (1985). Acidentes do trabalho: uma forma de violência. In *Acidentes do trabalho: uma forma de violência*.
- Couto, H. de A. (2014). Ergonomia do Corpo e do Cérebro no Trabalho. *Belo Horizonte: ERGO*.
- EU-OSHA, A. E. para a S. e S. no T. (2018). Lesões musculoesqueléticas - Segurança e saúde no trabalho - EU-OSHA. Retrieved from <https://osha.europa.eu/pt/themes/musculoskeletal-disorders>

- Gómez-Galán, M., Pérez-Alonso, J., Callejón-Ferre, Á.-J., & López-Martínez, J. (2017). Musculoskeletal disorders: OWAS review. *Industrial Health*. <https://doi.org/10.2486/indhealth.2016-0191>
- lida, I. (1990). Ergonomia: projeto e produção. *São Paulo: Editora Edgard Blucher*.
- lida, I. (2005). projeto e produção. *São Paulo: Editora Edgard Blucher*.
- Lourinho, M. G., Vieira, E. R., Almeida, L. B. de, Quemelo, P. R. V., & Negreiros, G. R. (2012). Riscos de lesão musculoesquelética em diferentes setores de uma empresa calçadista. *Fisioterapia e Pesquisa*, 18(3), 252–257. <https://doi.org/10.1590/s1809-29502011000300009>
- Nunes, F. (2008). Otimizando a Evisceração Automática. Ergomix - Avicultura - Artigos técnicos. Retrieved from <https://pt.engormix.com/avicultura/artigos/evisceracao-automatica-aves-t36734.htm>
- Takeda, F., Oliveira, C. C. de, & Xavier, A. A. de P. (2009). Aplicação do método OWAS para avaliação postural na linha de cortes de um Frigorífico de Aves, 1. Retrieved from [http://www.fecilcam.br/anais/iii\\_eepa/pdf/8\\_01.pdf](http://www.fecilcam.br/anais/iii_eepa/pdf/8_01.pdf)
- Teixeira, D. L. P., & Souza, M. C. A. F. de. (2013). Organização do processo de trabalho na evolução do capitalismo. *Revista de Administração de Empresas*. <https://doi.org/10.1590/s0034-75901985000400007>
- Uva, A., Carnide, F., Serranheira, F., Miranda, L., & Lopes, M. F. (2008). Lesões Musculoesqueléticas Relacionadas com o Trabalho: Guia de Orientação para a Prevenção. *Programa Nacional Contra as Doenças Reumáticas*, 28. <https://doi.org/274779/08>
- UVA, António Souza; CARNIDE, Filomena; SERRANHEIRA, Florentino, et al. Lesões Musculoesqueléticas Relacionadas com o Trabalho – Guia de Orientação para Prevenção. Direcção-Geral da Saúde. 2008.
- WOOD, Ellen Meiksins. A origem do capitalismo. Tradução de Vera Ribeiro. Rio de Janeiro: Jorge Zahar Editor, 2001.

## Prevalence of occupational diseases in women in Universities: Review Article

Maria I. Santos<sup>1</sup>, Marcelo M. Ribeiro<sup>2</sup>, Radigande Silva<sup>3</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT (up201802223@fe.up.pt) ORCID: 0000-0003-0148-1144, <sup>2</sup>Faculty of Engineering, University of Porto, PT (marcelomontebello@gmail.com) ORCID: 0000-0003-4945-5172, <sup>3</sup>Faculty of Engineering, University of Porto, PT (up201809126@fe.up.pt) [https://doi.org/10.24840/978-972-752-260-6\\_0034-0039](https://doi.org/10.24840/978-972-752-260-6_0034-0039)

### Abstract

**Introduction:** The research hereby presented is about the disease process of the working woman, understood from a socio-historical perspective of the worker. When talking about workers, specifically about women, various factors influence their entry into the job market. It can be perceived that the work division by gender contributes to the inequalities between women and men in several ways, particularly when it comes to health. When not dealing with the existing differences between social gender conditions, these can affect in the comprehension of work for women, in their working conditions and consequently, in matters related to the health prevention at work. **Objective:** To identify the prevalence of occupational diseases within women in universities. **Methods:** This systematic review was elaborated taking as a basis the PRISMA Statement methodology, retrieving articles from the Scopus and Web of Science electronic databases, and associating the prevalence of occupational diseases within women in universities. Obtained The obtained information was be analyzed along with the official data provided by the International Labour Organization-ILO and the World Health Organization-WHO. **Discussion.** Searches provided outcomes about the evidence on the technologies, benefits and even discussions on how the working conditions particularly affect women and represent potential causes of diseases that can negatively impact the quality of life at work, and therefore, prove the need of comprehensive data collection with the aim of contributing to modify that reality. Within studies, initial considerations promote the possibility of deepening knowledge with new searches. **Conclusions:** Results demonstrate the importance of perceiving the diseases within specific professional categories, hereby represented by the health professionals, professors, and administrative technicians. The article brought the contribution of studies that prove the importance of perceiving the female worker's profile, considering besides age, the associated diseases as well as the diseases that despite not being declared as occupational, perturb the work environment and need to be deepened as such. From the studied articles, this work proves the need for extending the searches oriented to perceive the factors that cause the highest percentages of diseases within women.

**Keywords:** Prevalence, Occupational diseases, Women, Universities.

### INTRODUCTION

The research consists of a reflection on the process of illness of women university workers. According to the report of the International Labour Organization (The International Labour Organization, 2018), it points out that women tend to have more responsibilities. As can be seen in the ways in which they enter the labour market and other aspects of their living and working conditions, reconciling them with their own and their families' reproductive activities has implications for health care. The different effects of risks and illnesses differ between men and women, both in the possible higher rates of illness, which can impact on reproductive health risks, the physical demands of heavy work, the ergonomic design of workplaces, the length of the working day and domestic tasks. These issues require a more gender-sensitive approach to research and prevention. The European Agency for Safety and Health at Work considers that the gender approach to safety and health at work cannot be considered neutral, as it has contributed to forms of illness and has harmed women and left a vacuum in specific policies and legislation. Given this fact, it was defined that this theme would have a place in the Research Priorities in the field of occupational safety and health in Europe: 2013-2020 (Centro Temático – Segurança e Saúde no Trabalho, Sas, & Suarez, 2014). When dealing with occupational diseases to which women are exposed, it is necessary to consider that there are important differences between men and women, the entire work process deserves to be recognized, as well as the social factors that measured labor relations, economic and cultural issues. The understanding of these interrelationships is only possible with the use of gender and equity as categories of analysis of the work environment, which may make it possible to break with the idea of thinking about the health of women workers from the perspective of maternity or fragility. It is necessary to perceive norms as these relationships occur and, if sexist paradigms predominate, or

otherwise walks in the evolution towards the promotion of equality between men and women, essential for the construction of balance in relationships and working conditions. When we refer to the illness of women and labour relations, it is necessary to integrate the gender dimension in all research topics. It is of fundamental importance when we consider that there are still differences in social relations between the sexes, which leads to social inequalities. The agenda remains and is far from achieving equity. Current research on the use of women's time is predominantly on the responsibility of domestic work and they devote more time to this type of task. What proves in the resulting survey in the Annual Socioeconomic Report of Women of 2013, this affirms that among people aged 16 years or more, 68% of women declare to perform domestic chores, in opposition to 32% of men. In addition, among employed women, the dedication to domestic work is 22.3 hours per week, as opposed to 10.2 hours dedicated by men, which means that the total day of women, adding paid and unpaid work, is on average 58.5 hours per week, while that of men and 52.7 hours per week (Areias & Guimarães, 2004). Understanding gender is to understand the complex social processes through which people are defined and connected and how this evolution occurs over time. This process is intrinsic to all instances of society, whether institutional or not (Manandhar, Hawkes, Buse, Nosrati, & Magar, 2018). To pay attention to gender equality is also to think about economic growth. The data show that there has been great progress towards legal gender equality in the last decade, in 131 economies and 274 reforms of laws and regulations, which has made it possible to lead to an increase in gender equality. However, achieving gender equality requires more than just changes in laws. Even with all the changes that have occurred, a typical economy only gives women three-quarters of men's rights in the areas measured (average overall score is 74.71), indicating that a typical economy only gives women three-quarters of men's rights in the areas measured. To be truly and effectively implemented, changes must be sought, among others, ingrained cultural norms and attitudes ("Women, Bus. Law 2019," 2019). When considering this information, this study aims to know research that can bring data on the prevalence of occupational diseases in women in universities.

## METHODOLOGY

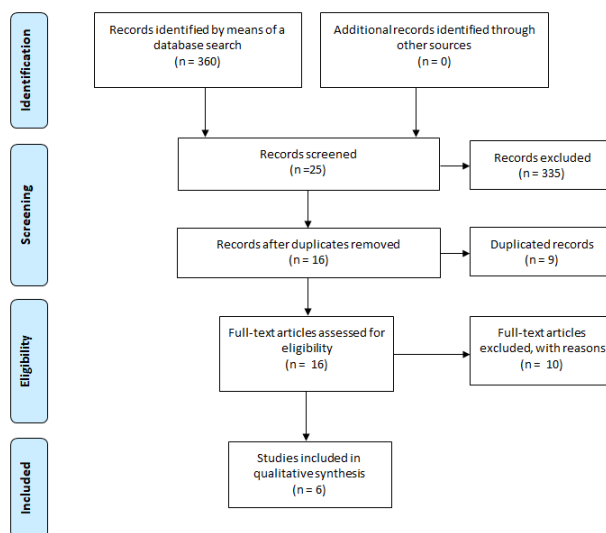
This systematic review was developed using the Prisma Statement tool (Moher, 2015), using the Mendeley manager. The Scopus and Web of Science databases were used to search for a combination of key words with the following combination: prevalence + disease + occupational in woman; prevalence + disease + occupational + woman + university from the objective of the study. The survey was conducted in the period from January 3 to 4, 2019. From the initial study, restrictions were made on articles that did not specify the issue of occupational diseases in women at universities, which include university hospitals and university training centers. The eligibility criterion covered the time interval from 2015 to 2018. The English language. The type of document were articles, and the sources were systematically reviewed and revised. The manual was read in a document of the International Labour Organization – ILO, Bulletin of the World Health Organization and Women and Business and the Law 2019. Lines below, Table 1 details the applied keywords and the respective number of articles resulted from them.

**Table 1.** Databases: Scopus and Web of Science

KEYWORDS	*SCOPUS	TOTAL	2015 TO 2019	AFTER ABSTRACT READING
Prevalence and disease occupational and women and universities		124	31	7
Disease occupational and women and worker universities		162	39	7
<b>KEYWORDS</b>	<b>*WEB OF SCIENCE</b>	<b>TOTAL</b>	<b>2015 to 2019</b>	<b>AFTER ABSTRACT READING</b>
Prevalence and disease occupational and women and universities		40	13	5
Disease occupational and women and worker universities		34	07	6
<b>Total</b>		25		
<b>Duplicates</b>		09		
<b>Read studies</b>		16		
<b>Studies excluded in total</b>		10		
<b>Studies included in the review article</b>		06		

\*DATE OF SEARCH: 3.1.2019

Figure 1 shows the Prisma Flowchart 2009 (Adapted) with the mapping of all the researches developed, resulting in the articles included for this review. Table 2 shows the included articles in this research.

**Figura 1.** Prisma 2009 Flow Diagram (adapted)



**Table 2.** Articles included in the systematic review.

1 <sup>st</sup> AUTOR	YEAR COUNTRY	TITLE (ORIGINAL)	TYPE OF STUDY	PREVALENCE/ILLNESS
<b>Nazmiye Koyuncu, Özgür Karcioglu</b>	2018 EEUU	Musculoskeletal complaints in healthcare personnel in hospital: An interdepartmental, cross-sectional comparison	Cross-sectional prospective study	Female gender, high income, university degree, nursing or medical work, and advanced age may demonstrate a higher prevalence of EMF in the hospital's PCS.
<b>Flavia D'agostin &amp; Corrado Negro</b>	2017 Italy	Symptoms and musculoskeletal diseases in hospital nurses and in a group of university employees: a cross-sectional study.	Cross-sectional study	The study confirmed the multifactorial origin of MSDs and showed that physical and psychosocial work factors (type of work, characteristics of physical burdens) and individual factors (female, advanced age) were associated with the prevalence of MSDs.
<b>Malin Lohela- Karlsson Et Al</b>	2018 Sweden	Perceived health and work-environment related problems and associated subjective production loss in an academic population.	Cross-sectional study	The prevalence of health problems only or a combination of work environment and health problems was higher among women than men (p-value < 0, 5).
<b>Arvidsson I, Et Al.</b>	2016 Sweden	Cross-sectional associations between occupational factors and musculoskeletal pain in women teachers, nurses, and sonographers.	Planned Prospective Cohort Study.	In women, the effect of working with computers at UEMSP has been considerably increased in the presence of emotionally demanding work, and can also be tempered by low recognition at work, contradictory demands at work and low support from the supervisor.
<b>Leão, Sylvia H. De S. Et, al</b>	2015 New Zealand	Voice problems in New Zealand teachers: a national survey.	Cross-sectional Epidemiological Survey	Women embarking on a teaching career can anticipate more voice problems than their male teaching colleagues; and therefore voice education is particularly vital for women entering the profession.
<b>Yun, M. J., Kim, Y. K., Kang, D. M., Kim, J. E., Ha, W. C., Jung, K. Y., &amp; Choi, H. W.</b>	2018 Republic of Korea	A Study on Prevalence and Risk Factors for Varicose Veins in Nurses at a University Hospital	Questionnaire and ultrasound examination	This study is significant in that an objective diagnosis of VVs preceded the analysis of the risk factors for VV incidence, thus verifying objectively that VVs are associated with occupations requiring prolonged hours of working in a standing position.

## RESULTS AND DISCUSSION

The searches bring information on the evidence of technologies, benefits and even discussions on how the working conditions particularly affect women, who denote potential reasons for diseases that could negatively alter their quality of life at work. Consequently, there is a need for deepening in collected information, with the goal of changing that reality. Within the first study, college graduation, nursing, and advanced-age doctors demonstrate a higher prevalence of musculoskeletal complaints (MSC) in the healthcare workers (HCWs) at a hospital (Koyuncu & Karcioglu, 2018). Musculoskeletal symptoms, in addition to the female gender condition and the ageing issue in the prevalence of the Work-Related Musculoskeletal Disorder-WMSD, the study of D'Agostin & Negro (2017), confirms the factors: psychosocial, the issue of female gender and ageing, in the prevalence of those diseases. The investigation from (Arvidsson et al.,

2016), affirms that both physical and psychosocial factors are associated with pain even though their studied groups present situations differently. In relation to professors, they indicate that there was a lower physical workload and improvements in the working environment should be guided to psychosocial aspects. On the other and, the surgical team in hospitals and the ultrasonographers can be benefited from preventive measures related to the physical workload, considering a reduction of hand strength demands among nurses. The work on the Prevalence of Symptoms and the Risk of the Obstructive Sleep Apnea Syndrome (OSA), evidencing a higher percentage of women (representing 67%) has an added value for (Cadelis & Fayad Y Monteagudo, 2016) to develop a screening on the OSA that could be later implemented within Occupational Health. In fact, the author states that it is not yet considered as an occupational disease. Reviewing the studies of (Lohela-Karlsson, Nybergh, & Jensen, 2018), female academic personnel demonstrate a higher prevalence of health problems resulted from a combination of the work environment factors and even evidence a higher severity on those health issues when compared to men. In the work developed by (Leão, Oates, Purdy, Scott, & Morton, 2015), it is stated that women with teaching careers can have more voice problems than their male colleagues. Authors do not discuss the causes for this fact. However, they indicate that the next research phase will be focused on investigating the potential factors leading to voice problems within professors in field conditions. The work of (Kim et al., 2017) studies varicose veins in nurses from a University Hospital. This investigation was developed to determine the occupational risk factors for VVs and their prevalence among the nursing workforce, considered as a high-risk occupational group. The author affirms that although the research was developed with a 90% of women and there were not conditions for comparison with men; there are indicators from past investigations (referenced in the article) that point out a higher risk for women.

## CONCLUSIONS

The articles read and analyzed demonstrate a greater perception of the prevalence of diseases in female workers at universities, represented here by women: health professionals, teachers and administrative technicians and incidence of diseases in certain professional categories, considering besides age, associated diseases. It also made it possible to perceive a disease that is not considered occupational, but that suggests studies in this direction, as it permeates the work environment and lacks deepening as such. This study is the first of some studies intended to make and contribute to the perception of the illness of female university workers and consequently considering the improvement in working conditions.

## References

- Areias, M. E. Q., & Guimarães, L. A. M. (2004). Gender and stress in workers of a public university of São Paulo state. *Psicologia Em Estudo, 9*, 255–262.
- Arvidsson, I., Gremark Simonsen, J., Dahlqvist, C., Axmon, A., Karlson, B., Björk, J., & Nordander, C. (2016). Cross-sectional associations between occupational factors and musculoskeletal pain in women teachers, nurses and sonographers. *BMC Musculoskeletal Disorders, 17*(1). <https://doi.org/10.1186/s12891-016-0883-4>
- Cadelis, G., & Fayad Y Monteagudo, O. E. (2016). Prévalence des symptômes et du risque de syndrome d'apnée obstructive du sommeil évaluée par le questionnaire de Berlin parmi les professionnels d'un établissement de santé. *Revue d'Epidemiologie et de Sante Publique, 64*(6), 405–414. <https://doi.org/10.1016/j.respe.2016.06.332>
- Centro Temático – Segurança e Saúde no Trabalho, Sas, K., & Suarez, A. (2014). Prioridades da investigação no domínio da segurança e saúde no trabalho na Europa: 2013–2020. *Agência Europeia Para a Segurança e Saúde No Trabalho, 24*. <https://doi.org/10.2802/92348>

- D'Agostin, F., & Negro, C. (2017). Symptoms and musculoskeletal diseases in hospital nurses and in a group of university employees: a cross-sectional study. *International Journal of Occupational Safety and Ergonomics*, 23(2), 274–284. <https://doi.org/10.1080/10803548.2016.1198092>
- Kim, Y.-K., Kang, D.-M., Jung, K., Choi, H.-W., Yun, M.-J., Ha, W.-C., & Kim, J.-E. (2017). A Study on Prevalence and Risk Factors for Varicose Veins in Nurses at a University Hospital. *Safety and Health at Work*, Vol. 9, pp. 79–83. <https://doi.org/10.1016/j.shaw.2017.08.005>
- Koyuncu, N., & Karcioğlu, Ö. (2018). Musculoskeletal complaints in healthcare personnel in hospital. *Medicine*, Vol. 97, p. e12597. <https://doi.org/10.1097/md.00000000000012597>
- Leão, S. H. D. S., Oates, J. M., Purdy, S. C., Scott, D., & Morton, R. P. (2015). Voice Problems in New Zealand Teachers: A National Survey. *Journal of Voice*, 29(5), 645.e1-645.e13. <https://doi.org/10.1016/j.jvoice.2014.11.004>
- Lohela-Karlsson, M., Nybergh, L., & Jensen, I. (2018). Perceived health and work-environment related problems and associated subjective production loss in an academic population. *BMC Public Health*, 18(1). <https://doi.org/10.1186/s12889-018-5154-x>
- Manandhar, M., Hawkes, S., Buse, K., Nosrati, E., & Magar, V. (2018). Gender, health and the 2030 Agenda for sustainable development. *Bulletin of the World Health Organization*, 96(9), 644–653. <https://doi.org/10.2471/BLT.18.211607>
- The International Labour Organization. (2018). *Global wage report 2018 / 19 what lies behind gender pay gaps*. Retrieved from [https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms\\_650553.pdf](https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_650553.pdf)
- Women, Business and the Law 2019. (2019). *Women, Business and the Law 2019*. <https://doi.org/10.1596/31327>

## Suicide and Work, Sociological View. Review article

Marcelo M. Ribeiro<sup>1</sup>, Maria I. Santos<sup>2</sup>, Radigande Silva<sup>3</sup>, Trajano F. B. X. Silva<sup>4</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT (up201802223@fe.up.pt) ORCID: 0000-0003-0148-1144, <sup>2</sup>Faculty of Engineering, University of Porto, PT (marcelomontebello@gmail.com) ORCID: 0000-0003-4945-5172, <sup>3</sup>Faculty of Engineering, University of Porto, PT (up201809126@fe.up.pt), <sup>4</sup>Faculty of Engineering, University of Porto, PT (up201802228@fe.up.pt) ORCID: 0000-0001-7168-4161  
[https://doi.org/10.24840/978-972-752-260-6\\_0040-0045](https://doi.org/10.24840/978-972-752-260-6_0040-0045)

### Abstract

**Introduction** For more than a century, the sociological study of suicide is due to Durkheim's classic *Suicide*. Essentially there are two central principles: that the structure of suicide rates in a society is a function of the structure of social relations and that vary in terms of integration and/or regulation. Suicide occurs predominantly among the group with the highest levels of social, political and religious solidarity. However, when Durkheim's theory is extended, and extension in the micro level is integrated. When individuals do not feel integrated into society, they can commit selfish suicide. In the ultimate analysis, higher levels of suicide in modern societies would reach equilibrium due to the stabilizing forces related to mutual interdependence and social mobility. **Objective:** This study aimed to characterize the studies produced in the last 5 years that address suicide and its main causes. **Methodology:** a systematic review that followed the reporting guidelines of PRISMA methodology to obtain relevant to the subject data was performed. The review was based on relevant articles published in three databases (SCOPUS, Science Direct and Web of Science). The keywords used were Suicide, Sociology and Military. The eligibility criteria of the articles contemplated only articles published and peer reviewed, published from 2014 to 2019, and written in English. **Results and Discussion:** 149 articles were selected, of which 8 studies were included, after applying the date criteria (period 2014 to 2019); document type criteria (only research articles) and the language criteria (articles in English). **Conclusion:** It is worth mentioning that little change has occurred in existing social theories, however, society is evolving, is the interpersonal mechanism at work or family. Such relationships between friends, the influences of mourning, require special attention.

**Keywords:** Suicide, Sociology, Military.

### INTRODUCTION

In his literary work "*Suicide*", Durkheim led to Tarde's "imitation" thesis, but eventually consider imitation as "a purely psychological phenomenon." (Abrutyn & Mueller, 2014a). It is clear that Durkheim's dismissal probably had more to do with the implications of Tarde's social psychological theory for his own suicide theory. As such, he has established a strategy to accept "that the idea of suicide can undoubtedly be communicated by contagion .... [and that] no other phenomenon is more readily contagious", while at the same time, arguing that the social rate of suicide was of true sociological significance. Tarde's eventual marginalization in American sociology and the conventional wisdom that Durkheim "won" the debate obscure a critical question: whether it is worth recapturing Tarde's social psychological theory about the diffusion of emotions, ideas and behaviors (Abrutyn & Mueller, 2014a). Durkheim argues in his famous work, *Suicide* that variations in the suicide rate in any country are related to the level of social integration and social regulation in the country. To further highlight more his theory, he outlines a typology of suicide that differentiates four types of suicide: selfish, altruistic, anomic, and fatalistic suicides (Edwards, 2016). When individuals do not feel integrated into society, they may commit selfish suicide (Ritz e Goodman, 2004). Individuals who are not well integrated into society feel that they are not part of the community, but the community also feels that individuals do not fit into their lifestyle (Recker & Moore, 2016). In this spirit, this article asks: How can we bring cultural sociology into dialogue with the structuralism of Durkheim's theory to better understand the social roots of suicide. Although Jack Douglas (1967) first drew attention to the importance of cultural meanings for the understanding of suicide, thinking about culture and suicide was widely undertaken by anthropologists, undermining efforts to generate a generalizable sociological theory (Abrutyn & Mueller, 2018). Although the sociology

of suicide has generally neglected the idea of culture, there is some evidence in both sociology and other disciplines that culture is important for suicide. In 1967 sociologist Jack Douglas was one of the first to defend an argument for analyzing culture in relation to suicide. Specifically, he argued that the effectiveness of the study of suicide rates in the Durkheimian's tradition was hampered by our lack of understanding of how society gives meaning to suicide. His evidence for this were substantial inconsistencies and now well documented; (Rockett, Samora & Coben 2006) in official statistics of suspicious deaths as suicides (Abrutyn & Mueller, 2014a). The question that gives the sense to this research is based on the need to know the main causes of suicide that are reported in articles published in a certain period of time. Based on previous statements, this study aimed to characterize the studies produced in the last 5 years that address suicide and its main causes.

## METHODOLOGY

The review methodology used followed the guidelines for reporting the methodology PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher et al, 2009; Liberati et al., 2009). The systematic search was focused on the literature regarding suicide and its main causes. The search strategy consisted of a comprehensive search that could locate the widest spectrum of articles for the aforementioned subject and was carried out in selected electronic databases, namely: Scopus, Science Direct and Web of Science. For each electronic database used, the search terms were as follows: Suicide. Sociology; Military. The Articles eligibility criteria contemplated only research articles published and peer reviewed, where information about suicide causes were found. Only papers published in the period from 2014 to 2019 and written in English were considered. It was admitted a possible bias inherent in the fact that non-English works were excluded from the search process. All studies considered for in-depth analysis were critically evaluated in questions such as the quality and content of the research methodology and the outcomes of the study. This evaluation is significant to minimize the bias of individual studies and thus prevent the inclusion of data that may compromise the acuity of the results of this review.

## RESULTS

The entire details of the selection criteria processes are summarized in Figure 1. After screening and eligibility processes, thirteen articles were considered relevant to the study topic, Table 1.

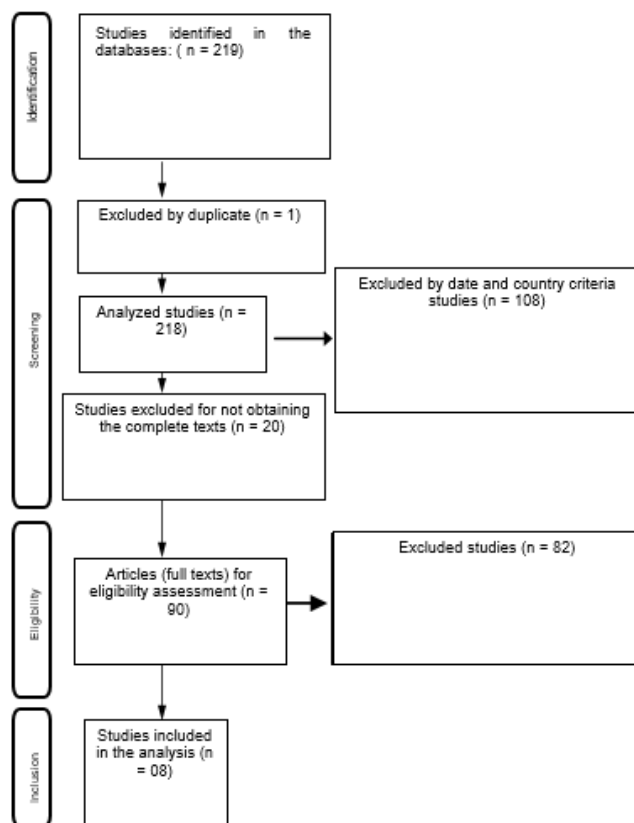
### Analysis of bias

Information or samples bias were not identified in the included articles, as they did not present contamination of information, in view, the theoretical analysis.

## DISCUSSION

As an investigation question of this systematic review, the suicide, uncovered ways of investigation for the prevention of suicide, taking into account two basic types: suicide and self-inflicted injury; this second as the main cause of suicide, World Health Organization (WHO, 2014) data, are more than 804,000 cases worldwide and 25% more self-inflicted injuries. In the words of the General Director of the World Health Organization, this level of suicide in any country is sufficient to classify suicide as a public health problem and to investigate its causes and consequences (Edwards, 2016). If people expect to live in a democratically governed society

rather than imperial subjects, they must know where to apply moral and political influence (Worrell, 2015). The various characteristics of suicide and its consequences comprise what the sociologist Donald Black would call "social case geometry". Using Black's theoretical language, the law in the case of Isabel flows down through a great distance in "social space," a state centralized to an individual who was under the direct authority of the state and had lower social status. As Black's theory predicts, cases with this kind of social geometry attract the strongest legal responses (Tucker, 2015). However, other analyses of social capital and suicide showed that areas with high social capital increased suicide rates. Flavin & Radcliff (2009) examined social capital and suicide by the state in the United States. Using Putnam's index of social capital, the authors found that, as the index of social capital increased, suicide rates increased.



**Figure 1.** Flowchart of identification and selection of articles for systematic review.

Thus, they argued that social capital increased suicide. This conclusion is in line with the arguments of Kushner & Sterk (2005), who examined Durkheim's arguments on social integration and social regulation. They argued that high levels of social capital should increase suicides and affirmed that high levels of social integration were correlated with suicide (Recker & Moore, 2016). Cultural scripts - models for sequencing behavior over time - are similar to Swidler's concept of action strategies, as they both specify how to achieve desired outcomes or solve problems. In addition to guiding behavior within intimate environments, relationship scripts are crucial in developing ideal selves related to the roles of romantic and intimate partners (Soller, 2014).

**Table 1.** Studies of suicide and its main causes (8 studies)

Title	Author	Date	Objective	Summary
Reconsidering Durkheim's Assessment of Tarde: Formalizing a Tardian Theory of Imitation, Contagion, and Suicide Suggestion.	Abrutyn, S., & Mueller, A. S.(2014b)	2014	Revisiting Tarde, the paper examines why Tarde's theory	Emile Durkheim rejected the imitation of Gabriel Tarde's thesis, arguing that sociology only has to worry about the rates of social suicide.
Toward a Cultural-Structural Theory of Suicide: Examining Excessive Regulation and Its Discontents.	Abrutyn, S., & Mueller, A. S.	2018	Despite his enduring perceptions, Durkheim's suicide theory.	We conclude with implications for future sociological research on suicide and suicide prevention.
Suicide in Guyana: a Parsonsian corrective to Durkheim's theory of suicide.	Edwards, D. C.	2016	The present paper aims to make the point that Durkheim's theory of suicide requires a theoretical extension.	Suicide occurs predominantly among the group with the highest levels of social, political and religious solidarity.
Socio-Economic Development, Economic Fluctuations, and Age-Specific Suicide: A Cross-National Test of the Durkheim, Henry, and Short, and Ginsberg Theories. <i>The Sociological Quarterly</i>	Piatkowska, S. J.	2018	This study is based on Durkheim, Henry, Short, and Ginsberg theories.	We used a set of grouped transactional time series data, composed of 17 Western European nations, covering a period of more than 50 years (1956 to 2012).
Durkheim, social capital, and suicide rates across US counties.	Recker, N. L., & Moore, M. D.	2016	Finding out whether there are municipalities with higher rates of social capital, diversity and population density have experienced lower rates of suicide.	Suicide is a very contemporary issue. This paper draws on Durkheim's approach, using social capital theory as a framework for examining suicide rates.
Caught in a Bad Romance. <i>Journal of Health and Social Behavior</i>	Soller, B.	2014	Applying the sequence analysis to data from the National Longitudinal Study of Adolescent Health.	Integrating insights from cultural sociology and identity theory.
The geometry of suicide law. <i>International Journal of Law, Crime, and Justice</i>	Tucker, J.	2015	In this article, Donald Black's theory of law and social control is applied to explain the variation in suicide law.	It focuses on the three variable characteristics of the social geometry of a suicide case - the centralization of the state in which Self-death occurs, the relationship of the Auto assassin with the state and the social status of the Auto-assassin.

Title	Author	Date	Objective	Summary
Imperial Homunculi: The Speculative Singularities of American Hegemony	Worrell, M. P.	2015	This article explores the domain of symbolic imagery to understand the mechanisms and effects of neoliberal deregulation	Instead of something that needs to be defeated, terror is an enemy that cannot be defeated, but it cannot prevail against an empire either.

Durkheim proposes a type of suicide resulting from being very integrated. Durkheim solved this dilemma by arguing that "inferior societies are the theater by excellence of altruistic suicides," with only the most exceptional cases - such as the soldier throwing himself on a grenade to save his unit to be present in modernity - an assertion that lacks empirical validity (Abrutyn & Mueller, 2014a). The society also has to regulate the behavior of the individual. Durkheim described anomic suicide as suicide when societal regulation is disrupted (Ritzer e Goodman, 2004). The rupture can occur during an economic boom or depression. The interruption leaves individuals with little guidance as to the norms and values that apply to the new situation, or to those who should be following. This lack of regulation leaves some people feeling overwhelmed and increases suicide in society (Recker & Moore, 2016). This brief review demonstrates the sophistication of Tarde. Imitation was not psychological, but psychological social. As Kral (1994) and others (Katz, 1999) have argued convincingly, ideas not only jump from one mind to another but must be communicated: "An idea, once planted, can become easily accessible and difficult to replace." it may seem simplistic to suggest that telling someone about their thoughts, plans, or suicidal attempts will contribute to the spread of these behaviors, but it does bring suicidal suggestions to the social psychological world of Tarde (Abrutyn & Mueller, 2014a). A careful reading of his chapter, Durkheim, on altruism reveals a very emotional discourse: he postulates that the egoist suffers from "feelings of incurable fatigue and sad depression," while the motivation of the altruist "springs from hope... because it depends on the belief in beautiful perspectives beyond this life. . . [and] implies even the enthusiasm and impulse of a faith that earnestly seeks satisfaction, affirming itself by acts of extreme energy " (Abrutyn & Mueller, 2014a). It is also known that social relations, groups, and environments are composed of recurrent and emotionally charged interactions that generate unique emotional profiles and biographies that are a mixture of intergroup relationships and idiosyncrasies and experiences of group members. This point is essential to understand and explain suicide because some groups probably have biographies and more intense negative emotional profiles due to their low-status position with other groups, biographies and exclusive emotional profiles of its members or the intersection of the same (Abrutyn & Mueller, 2014b).

## CONCLUSIONS

The systematic review proposed to answer the question of investigation regarding the possible causes of the suicidal act described in the literature. Overall, the results of the studies provided a clear vision of the determinants of the suicidal act. Due to the nature of the results, it was well evidenced that suicide is a multi-causal phenomenon and can be associated with the determinants of the most varied shades. The possibilities for the motivation to commit the suicide proposed by the authors give a good measure of this diversity. However, the act, conscientious and solitary, this being a desperate mechanism to end the anguish that only the individual experiences — affecting everyone around you — potentially causing mourning for your peers. Also, we cannot say that there is a form of prevention for the suicide act or its ideation. It is pointing thus to need more studies on the subject. Taking into account the ethical and aesthetic standards of research, to register that in the face of the transversal theme,



transdisciplinary attention it is necessary: Biological, Psychological and social. Considering indispensable the dialogue between the knowledge and the long way for the search for possible suicide prevention. It is noteworthy that little change occurred in existing social theories; however, society is in evolution, either the interpersonal mechanism at work or in the family. Such relationships between friends, the influences of mourning, require special attention.

## References

- Abrutyn, S., & Mueller, A. S. (2014a). Reconsidering Durkheim's Assessment of Tarde: Formalizing a Tardian Theory of Imitation, Contagion, and Suicide Suggestion. *Sociological Forum*, 29(3), 698–719. <https://doi.org/10.1111/socf.12110>
- Abrutyn, S., & Mueller, A. S. (2018). Toward a Cultural-Structural Theory of Suicide: Examining Excessive Regulation and Its Discontents. *Sociological Theory*, 36(1), 48–66. <https://doi.org/10.1177/0735275118759150>
- Douglas, J. D. (1967). The Social Meanings of. Suicide.
- Edwards, D. C. (2016). Suicide in Guyana: a Parsonsian corrective to Durkheim's theory of suicide. *Canadian Journal of Latin American and Caribbean Studies / Revue Canadienne Des Études Latino- Américaines et Caraïbes*, 41(2), 197–214. <https://doi.org/10.1080/08263663.2016.1189650>
- Flavin, P., & Radcliff, B. (2009). Políticas públicas e taxas de suicídio nos estados americanos. *Social Indicators Research*, 90 (2), 195-209.
- Kushner, H. I., & Sterk, C. E. (2005). The limits of social capital: Durkheim, suicide, and social cohesion. *American journal of public health*, 95(7), 1139-1143.
- Katz, J. (1999). *Como as emoções funcionam*. Imprensa da Universidade de Chicago.
- Kral, MJ (1994). Suicídio como lógica social. *Suicídio e Comportamento de Ameaça à Vida*, 24 (3), 245-255.
- Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., ... & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS medicine*, 6(7), e1000100.
- Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of internal medicine*, 151(4), 264-269.
- Piatkowska, S. J. (2018). Socio-Economic Development, Economic Fluctuations, and Age-Specific Suicide: A Cross-National Test of the Durkheim, Henry and Short, and Ginsberg Theories. *The Sociological Quarterly*, 59(3), 471–494. <https://doi.org/10.1080/00380253.2018.1479201>
- Recker, N. L., & Moore, M. D. (2016). Durkheim, social capital, and suicide rates across US counties. *Health Sociology Review*, 25(1), 78–91. <https://doi.org/10.1080/14461242.2015.1101703>
- Ritzer, G. e Goodman, DJ (2004). Teori sosiologi moderno. *Jakarta: Prenada Media*, 121 .
- Rockett, I. R., Samora, J. B., & Coben, J. H. (2006). The black–white suicide paradox: Possible effects of misclassification. *Social science & medicine*, 63(8), 2165-2175.
- Soller, B. (2014). Caught in a Bad Romance. *Journal of Health and Social Behavior*, 55(1), 56–72. <https://doi.org/10.1177/0022146513520432>
- Tucker, J. (2015). The geometry of suicide law. *International Journal of Law, Crime and Justice*, 43(3), 342–365. <https://doi.org/10.1016/j.ijlcrj.2015.05.007>
- Worrell, M. P. (2015). Imperial Homunculi: The Speculative Singularities of American Hegemony (Drones, Suicide Bombers, and Rampage Killers, or, an Excursion into Durkheimian Geometry) (pp. 217–241). <https://doi.org/10.1108/S0278-120420150000033008>
- World Health Organization (WHO). (2014). Preventing suicide: a global imperative. Geneva: WHO.

## Virtual Reality and the future of construction

Adeeb Sidani<sup>1</sup>, J. Duarte<sup>2</sup>, Fábio Dinis<sup>3</sup>, Luís Sanhudo<sup>4</sup>, J. Santos Baptista<sup>5</sup>, João Poças Martins<sup>6</sup>, Alfredo Soeiro<sup>7</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT ([adeeb.sidani@hotmail.com](mailto:adeeb.sidani@hotmail.com)), <sup>2</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([jasduarte@fe.up.pt](mailto:jasduarte@fe.up.pt)) ORCID 0000-0002-5856-5317, <sup>3</sup>CONSTRUCT - GEQUALTEC, Faculty of Engineering, University of Porto, PT ([fabiodinis@fe.up.pt](mailto:fabiodinis@fe.up.pt)), <sup>4</sup>CONSTRUCT - GEQUALTEC, Faculty of Engineering, University of Porto, PT ([lpnsanhudo@fe.up.pt](mailto:lpnsanhudo@fe.up.pt)) ORCID 000-0002-2578-6981, <sup>5</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([jsbap@fe.up.pt](mailto:jsbap@fe.up.pt)) ORCID 0000-0002-8524-5503, <sup>6</sup>CONSTRUCT - GEQUALTEC, Faculty of Engineering, University of Porto, PT ([jppm@fe.up.pt](mailto:jppm@fe.up.pt)), <sup>7</sup>Faculty of Engineering, University of Porto, PT ([avsoeiro@fe.up.pt](mailto:avsoeiro@fe.up.pt)) [https://doi.org/10.24840/978-972-752-260-6\\_0046-0050](https://doi.org/10.24840/978-972-752-260-6_0046-0050)

### Abstract

**Introduction:** Despite the recent trends in technology, construction projects are becoming increasingly challenging, which, in the result, brings in more complex and dynamic construction environments. In fact, traditional management and monitoring methods are currently unable to keep up with the industry's quick development, leading to several problems in task efficiency and transfer of information between stakeholders. As a result, the Architecture Engineering Construction and Operations (AECO) sector is making use of the digitalization in order to improve project management, assist trade-crews and achieve a more proficient working environment. The adoption of Building Information Modelling (BIM) embodies a paradigm shift from the traditional approaches towards a collaborative and integrated working process. Though BIM is improving the aforesaid issues, not every construction entity can easily adapt and use it successfully. Therefore, supportive tools to assist BIM in achieving its full potential are in high demand. **Objectives:** The current research objective is to provide a review of previous works in the field of BIM-based Virtual Reality (VR), in order to establish a clear view of this research field. This work provides the primary data on such goals. **Methodology:** In order to conduct the research, the PRISMA Statement strategy was used. The selected primary keywords were "construction", "virtual reality" and "building information modelling" and their variants. The research was carried out in the main engineering databases and journals, being Scopus, Science Direct and IEEE Xplore some examples. **Results:** After the identification of 2,950 records, exclusion criteria were applied: year of publication, type of document, type of source and de-duplication. The titles and abstracts of the publications were screened in order to determine the scope of the papers, leaving for full-text analysis just 75 studies. After going through the eligibility criteria, only 14 papers remained. Using the snowballing technique, two more papers were added to the study, resulting in 16 included papers. Most of the papers focused on the Construction Design, Construction Management, and Construction Safety fields, being "design" the most occurring construction stage. The highlighted target groups for the VR interfaces were Engineers, Architects and Workers. Most system architectures comprise, at least, three layers regarding a BIM software tool, a visual enhancement module and a game engine to provide the virtual environment and interaction functionalities. However, some studies referred to a fourth layer (database). **Conclusions:** The BIM-VR relation addressed in the articles was mainly focused on the model's geometric information since BIM provides an accurate display of building geometry. Most VR interfaces do not possess a database component to provide access to BIM parametric information, leading to the conclusion that BIM is not achieving its full potential with VR tools.

**Keywords:** Construction, Digitalization, Interface, Virtual Reality, BIM.

## INTRODUCTION

The Architecture Engineering Construction and Operations (AECO) sector is continuously faced with increasingly complex and competitive projects (Chan, Scott, and Chan 2004, Pham et al. 2017). To this end, the dissemination and implementation of Building Information Modelling (BIM) in the last few years contributed to pursue higher performance and accuracy in its processes through the digitalization (Antwi-Afari et al. 2018, Li et al. 2017, Succar 2009). BIM supports information creation, management, storage and exchange, and has the ability to apply it to a buildings' lifecycle (Sanhudo et al. 2018). However, the uptake rate of BIM has been slower than originally expected (Walasek and Barszcz 2017), as users lack the knowledge to take full advantage of its potential for communication (amongst project teams), exportation and visualization of the project, among others. On the other hand, Virtual Reality (VR) has shown encouraging developments, showing potential benefits with diverse applications, especially when taking advantage of accuracy and information comprised in BIM models (Li et al. 2017). Therefore, BIM-based VR applications have shown many advantages to boost design review, team collaboration, decision making, among others. As such, the goal of this short paper is to provide the primary data results analysis concerning recent advances in this field, enabling a

clear view of the research the sector produced in generating immersive VR environments from BIM.

## METHODOLOGY

The study methodology was based on the systematic review protocol of Sidani et al. (Sidani et al. 2018), where the Preferred Reporting of Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used (Moher et al. 2009). The following databases and journals were screened: Academic Search Complete, Current Contents, Web of Science, SCOPUS, INSPEC, ScienceDirect, Cambridge Journals Online, Directory of Open Access Journals, Emerald Fulltext, Informaworld (Taylor and Francis), Oxford Journals, SAGE Journals Online, Scientific Electronic Library Online, SpringerLink, Wiley Online Library, ACM Digital Library, ASME Digital Collection, CE Database (ASCE), IEEE Xplore, IOP Journals, ScienceDirect (eJournals), and SIAM. The core keywords were “construction”, “virtual reality” and “building information modeling”. However, keyword variations were also used.

## RESULTS AND DISCUSSION

A total of 2,950 records were identified through database searching. Then, applying the exclusion criteria, 748 were excluded by date (prior 2007), 957 by type of article (reviews, book chapters), 375 by type of source (apart from trade publications), and 18 due to language (other than English). Title and abstracts were screened, leading to the rejection of 464 papers (off topic) and an additional 313 records (duplicates) were removed. The 75 remaining papers were full-text screened in order to conduct the eligibility criteria phase. Only 14 papers remained after both screening processes. A final search was performed on the references of the articles that achieved the inclusion criteria stage. From this new search, two new articles were added to the research, resulting in a total of 16 articles. The summary of the research can be observed in Figure 1.

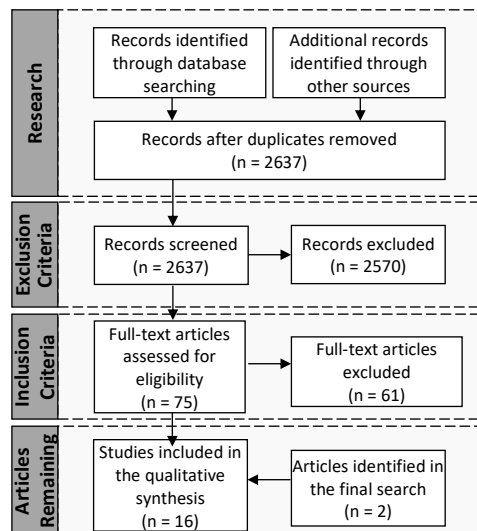


Figure 1. Research strategy based in PRISMA Statement

Most of the 16 (Table 1) selected studies focused on enhancing teamwork, communication and cross-team interaction, which is a common objective for VR related articles in general. The highlighted fields were Construction Design, Construction Management, and Construction Safety and the most occurring construction stage was design. As for the target groups, the

available research showed that Engineers, Architects, and Workers are typically the target users for the VR interfaces.

**Table 1.** Selected articles' construction stage, targeted group and researched BIM dimension

Author	Construction Stage	Target Group	BIM Dimension
(Lin, Chen et al. 2018)	• Design	• Owners • Architects • Engineers	• 3D
(Boton 2018)	• Design • Pre-construction • Construction	• Owners • Architects • Engineers • Workers	• 3D • 4D
(Wang, Li et al. 2018)	• Design	• Engineers • Students	• 3D • 5D • 7D
(Du, Shi et al. 2017)	• Design • Pre-construction • Construction • Operation and management	• Owners • Architects • Engineers • Workers • Facility managers	• 3D • 4D • 5D • 6D • 7D
(Cárcamo, Trefftz et al. 2017)	• Design	• Owners • Architects • Engineers	• 3D
(Jensen 2017)	• Design	• Students	• 3D
(Azhar 2017)	• Pre-construction • Construction	• Engineers • Workers	• 3D • 4D
(Wu, Wu et al. 2017)	• Design	• Students	• 3D
(Natephra, Motamedi et al. 2017)	• Design	• Owner • Architects • Engineers	• 3D • 5D
(Shi, Du et al. 2016)	• Operation and management	• Facility managers • Users	• 3D • 6D
(Hilfert and König 2016)	• Design • Construction	• Architects • Engineers • Workers	• 3D • 4D
(Edwards, Li et al. 2015)	• Design	• Users	• 3D
(Sacks, Whyte et al. 2015)	• Design • Construction	• Architects • Engineers • Workers	• 3D • 4D
(Gurevich and Sacks 2014)	• Construction	• Workers	• 3D • 4D
(Wang, Li et al. 2014)	• Design • Operation and management	• Users	• 3D • 4D • 6D
(Sacks, Gurevich et al. 2013)	• Construction	• Workers	• 3D • 4D

Regarding the hardware and software uses, most system architectures comprise at least three noteworthy layers:

- a BIM software tool, to provide an accurate 3D representation of the building in the study;

- a visual enhancement module, for compatibility between game engines and BIM authoring tools, model optimization and visual improvement;
- and a game engine, to provide the immersive virtual environment and interaction functionalities.

Finally, some studies expand to a fourth layer, including a database component to access the model's parametric information. Regarding validation, the greater part of the authors conducted case studies to test their proposed interfaces. However, among the 12 case studies found, six were combined with questionnaires and three mentioned conducting pilot tests. Overall, it was not found a holistic methodology or assessment framework towards the validation of BIM-based VR interfaces. Although quite a few limitations are offered regarding the use of VR laboratory experiments in opposition to field trials, the authors concluded that the use of VR increased both the reliability and the accuracy of the experimental results, as well as reduced the time needed to perform the experiment. It should be stated that while authors reinforce most of their choices throughout the studies, there exists a noticeable lack of information on the applied software. That is, despite the fact that the performance of most VR interfaces is directly dependent on the specifications of the equipment being used.

## CONCLUSIONS

The essential idea behind the reviewed virtual reality applications is to enable collaboration and communication, allowing people with different expertise to access BIM information. Most of the BIM-based VR applications use a three-layer system architecture comprised of a BIM authoring tool, a game engine, and a visual enhancement module. Some studies expanded to a fourth layer (database) in order to exchange the non-geometric information. A great part of the studies lack a complete justification concerning the reason for selecting the applied tools. Additionally, it should be stated that most papers did not provide hardware specification despite its potential impact on the system's performance. From the selected contributions it was concluded that the most researched stage of the projects' lifecycle was designed (the aim of 12 of 16 occurrences). Most interfaces were assessed by case studies, with half of these further supporting and validating the results with questionnaires. Additionally, three articles also conducted pilot tests to ease the user experience with the created VR interface. As seen in (Nielsen 1994), this approach is recommended when dealing with interfaces that mark a transition between more traditional approaches, in order to eliminate possible biases during the evaluation process created from the users' excessive effort with the innovative interface. The relation of BIM and VR in the articles was mainly focused on the model's geometric information since BIM provides an accurate display of building geometry. Most VR interfaces do not possess a database component to provide access to BIM parametric information, leading to the conclusion that BIM is not achieving its full potential with VR tools. As such, future research could focus on handling the non-geometric data provided by BIM within immersive VR interfaces.

## References

- Antwi-Afari, MF, H Li, EA Pärn, and DJ Edwards. 2018. "Critical success factors for implementing building information modelling (BIM): A longitudinal review." *Automation in Construction* 91:100-110.
- Chan, Albert PC, David Scott, and Ada PL Chan. 2004. "Factors affecting the success of a construction project." *Journal of construction engineering and management* 130 (1):153-155.

Li, Xiao, Peng Wu, Geoffrey Qiping Shen, Xiangyu Wang, and Yue Teng. 2017. "Mapping the knowledge domains of Building Information Modeling (BIM): A bibliometric approach." *Automation in Construction* 84:195-206.

Moher, David, Alessandro Liberati, Jennifer Tetzlaff, and Douglas G Altman. 2009. "Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement." *Annals of internal medicine* 151 (4):264-269.

Nielsen, Jakob. 1994. *Usability engineering*: Elsevier.

Pham, Hai Chien, Akeem Pedro, Quang Tuan Le, Do-Yeop Lee, and Chan-Sik Park. 2017. "Interactive safety education using building anatomy modelling." *Universal Access in the Information Society*:1-17.

Sanhudo, Luís, Nuno MM Ramos, João Poças Martins, Ricardo MSF Almeida, Eva Barreira, M Lourdes Simões, and Vítor Cardoso. 2018. "Building information modeling for energy retrofitting—A review." *Renewable and Sustainable Energy Reviews* 89:249-260.

Sidani, Adeb Ziad, J Duarte, Fábio Matoseiro Dinis, J Santos Baptista, João Poças Martins, and Alfredo Soeiro. 2018. "The Impact of BIM-based virtual and augmented reality interfaces on health and safety in construction projects: protocol for a systematic review." *International Journal of Occupational and Environmental Safety* 2 (1):67-74.

Succar, Bilal. 2009. "Building information modelling framework: A research and delivery foundation for industry stakeholders." *Automation in construction* 18 (3):357-375.

Walasek, Dariusz, and Arkadiusz Barszcz. 2017. "Analysis of the adoption rate of building information modeling [BIM] and its return on investment [ROI]." *Procedia Engineering* 172:1227-1234.

# Analysis of the nutritional composition of the typical meals of the rural workers in the Muanza District in Sofala – Mozambique

Arminda Uachisso<sup>1</sup>, Patrícia Padrão<sup>2</sup>, Susana Carvalho<sup>3</sup>, Daniel Agostinho<sup>4</sup>, Olívia Pinho<sup>5</sup>

<sup>1</sup>Pedagogical University, MZ ([minderirene@yahoo.com.br](mailto:minderirene@yahoo.com.br)), <sup>2</sup>EPIUnit, Institute of Public Health, Faculty of Nutrition and Food Science, University of Porto, PT ([patriciapadrao@fcna.up.pt](mailto:patriciapadrao@fcna.up.pt)), <sup>3</sup>Faculty of Sciences, University of Porto, PT ([susana.carvalho@fc.up.pt](mailto:susana.carvalho@fc.up.pt)), <sup>4</sup>Pedagogical University, MZ ([agostinho.daniel@hotmail.fr](mailto:agostinho.daniel@hotmail.fr)), <sup>5</sup>REQUIMTE, Faculty of Nutrition and Food Science, University of Porto, PT, ([oliviapinho@fcna.up.pt](mailto:oliviapinho@fcna.up.pt)) ORCID 0000-0001-9477-8638

[https://doi.org/10.24840/978-972-752-260-6\\_0051-0055](https://doi.org/10.24840/978-972-752-260-6_0051-0055)

## Abstract

**Introduction:** Muanza district is located in Sofala province in central Mozambique, one of the poorest districts in the country. Here agriculture is the basis for the livelihood of many families, and their eating habits are based on products from their fields, especially cereals and tubers. The main objective was to characterize the dietary habits and the average nutritional intake of the peasants of Muanza and to propose adaptations to the habitual food in order to improve the adequacy of the nutritional intake of the population. **Methods:** The information about the usual dietary intake of the adult community living in Muanza was collected by observation for three days, typifying the three most frequent days in terms of dietary intake in the community. Foods were weighed, and the mean values of energy and macronutrients expressed in grams and contribution to the total energy value (TEV) were calculated using the Mozambican Food Composition Table. The nutritional composition of the "Nhakaka" (*Dioscorea cayennensis*) and "Minhanha" (*Dioscorea rotundata*) tubers was estimated by bromatological analysis. After analyzing the farmer's food nutritional composition, it was proposed improvements in their diet. **Results:** The structure of the daily dietary intake includes two meals per day. On day 1, one of the meals was composed of Yam (*Dioscorea sp*) and tea and the other included Xima (prepared meal of sorghum) and dried fish. On day 2, one of the meals was composed by *Dioscorea cayennensis* and tea and another included Xima and okra (*Abelmoschus esculentus*). On day 3, one of the meals was composed of *Dioscorea rotundata* and tea and the other included Xima and Nhemba beans (*Vigna unguiculata*). The average daily intake of energy was 1352 Kcal, the carbohydrate intake was 937 g (69.3% for TEV), fat was 100g (7.3% of TEV) and protein was 31.6g (23.4% of TEV). When we increased the diet with seeds and fruits, daily energy would increase to 2125 Kcal, carbohydrates 1121g (52.7% for TEV), protein 423g (20% for TEV), fat 582 g (27.3% for TEV). **Conclusions:** Muanza peasants had a low energy intake considering their pattern of physical activity, with a predominance of carbohydrates and very low fat. The average daily energy intake, as well as the fat intake, increases with the inclusion of seeds and fruits.

**Keywords:** Nutritional composition, *Dioscorea cayennensis*, *Dioscorea rotundata*, Rural workers.

## INTRODUCTION

The Muanza district is located in the central Mozambique province of Sofala, one of the poorest districts in the country, with a poverty level of 67%, according to data from the National Survey of Population Living Mozambique (Mussagy, 2014). Agriculture is the basis for the livelihoods of many of the district's rural residents in particular, and their eating habits are based on products from their farms, hence the menu of these families is basically low- diversified, high in carbohydrates. "Minhanha" (*Dioscorea rotundata*) and "Nhakaka" (*Dioscorea cayennensis*), are very consumed tubers in this region, although their domestication and cultivation is being done on a small scale, and their collection is done in the forest, unlike what happens in other regions of the Africa, where cultivation is practiced in large areas as part of the crop. Considering the physical activity exerted by the peasants and the expected monotony of the food intake, it is pertinent to know the nutritional intake of this population, in order to propose interventions that meet their nutritional needs.

### Objectives:

- To characterize the usual diet and nutritional intake of peasants from Muanza district;
- To evaluate the nutritional composition of *Dioscorea cayennensis* and *Dioscorea rotundata* tubers used for food;

- To propose adaptations to the habitual food in order to improve the adequacy of the nutritional intake of the population.

## METHODOLOGY

The methodology was based on the direct observation, in Muanza, of the day-to-day food of 20 peasants. The conversion of food into macronutrients was performed using the food composition table of Mozambique (Korkalo, L. H., 2011). The energy value and the calculation of its contribution to the total energy intake (TEV) were then calculated. The typical consumed tuber samples which are locally known as “Nhakaka” (*Dioscorea cayennensis*) and “Minhanha” (*Dioscorea rotundata*) which were collected in Muanza district were submitted into bromatological analysis. The analysis were initiated by washing, weighing 300g of the sample, slicing, drying in the shadow for a period of 10 days, and finally the grinding. The obtained flour was used for the bromatological analysis and the proteins were determined by the Kjeldahl method based on the determination of total nitrogen after the conversion factor 6.25; the fats were extracted by Soxhlet (solvent used as n-hexane) then removal of the solvent used; carbohydrates by the Munson-walker method; ashes by gravimetry; the determination of Na and K by flame photometry; P by colorimetry; and Mg and Ca by complexometry (first the determination of the Ca + Mg set, for further subtraction to obtain the Magnesium content). After analyzing the nutritional composition of the usual food of the peasants, improvements in food intake were proposed in order to improve their nutritional adequacy.

## RESULTS AND DISCUSSION

The observed daily food consumption (Table 1) was based on the consumption of food from their farms or harvested in the forest, with little food variety and low energy intake, given the physical activity exerted as peasants. The diet of these farmers was shown to be rich in carbohydrates but low in fat. The usual average daily intake of energy was 1352 Kcal, carbohydrate was 937 g (69.4% for TEV), fat was 100g (7.3% of TEV) and protein was 316g (23.3% of the TEV). With the inclusion of local foods such as fruits and seeds, the average daily energy will increase to 2125 Kcal, carbohydrates 1121g (52.7% for TEV), protein 423g (20% for TEV), fat 582 g (27.3% for the TEV) (Gomes, 2015). The proposal presented to obtain a diet relatively adequate to the work of the field increases the energy to 2125 Kcal, having increased the fats from 7.3% to 27.3%, which significantly contributes to the energy reinforcement. Regarding the nutritional composition of the analyzed tubers (Table 2), these are a good source of carbohydrates that provide energy for the worker in the field but must be consumed with other foods that guarantee the supply of fats, proteins and micronutrients. The lipid content in *Dioscorea rotundata* was 0.78%, similar to that found by Adepoju (2012), which was 0.8%, regarding protein value, which was 7.5% higher than Adepoju's value (2012) of 2.3%. For carbohydrates these were 70.49%, and Adepoju (2012) for the same parameter found 3.3% for *Dioscorea cayennensis* the lipids represented 0.83% and the value found by Adepoju (2017) in the nine specimens analyzed was between 0.07 and 1.20%; the value of protein 6.75% and Adepoju (2017) found values between 1.21 and 6.83%; with respect to carbohydrates, we have 72.19% for Muanza sample, and 17.08 to 37.26% for the analyses performed by Adepoju (2017). We can observe that the nutritional richness is different to highlight especially the carbohydrates that presented very high values when compared with the studies made by Adepoju in Nigeria.



**Table 1.** Workers' food intake and diet improvement proposal

<b>OBSERVED DIETARY INTAKE OF PEASANTS</b>					
<b>DAYS</b>	<b>Foods</b>	<b>NUTRITIONAL COMPOSITION</b>			
		<b>Energy (Kcal)</b>	<b>Proteins g (%TEV)</b>	<b>Carbohydrates g (%TEV)</b>	<b>Fats g (%TE V)</b>
<b>DAY 1</b>	<i>Dioscorea sp</i> 572g, xima 211g, dried fish 161g	1029	583g (56.6%)	257g (25%)	189g (18.4%)
<b>DAY 2</b>	<i>Dioscorea cayennensis</i> 297g, xima 211g, nhemba beans 100g	1422	193g (13.6%)	1178g (82.8%)	51g (3.6%)
<b>DAY 3</b>	<i>Dioscorea rotundata</i> 412g, xima 211g okcra 252g	1604	170g (10.6%)	1376g(85.7%)	57g (3.7%)
<b>PROPOSAL TO INCREASE NUTRITIONAL INTAKE ADEQUACY OF PEASANTS</b>					
<b>DAYS</b>	<b>Foods</b>	<b>Energy (Kcal)</b>	<b>Proteins g (%TEV)</b>	<b>Carbohydrates g (%TEV)</b>	<b>Fats g (%TEV)</b>
<b>DAY 1</b>	<i>Dioscorea sp</i> 572g, xima 211g, dried fish 161g + 100g peanut, 100g banana	1920	695g (36%)	629g (33%)	598g (31%)
<b>DAY 2</b>	<i>Dioscorea cayennensis</i> 297g, xima 211g, hembra beans 100g +100g sesame, 100g avocado	2181	280g (13%)	1266g (58%)	636g (29%)
<b>DAY 3</b>	<i>Dioscorea rotundata</i> 412g, xima 211g okcra 252g + 100g pumpkin seeds, 100g guava	2274	294g (13%)	1468g (64.5%)	512g (22.5%)

The average daily energy intake of the rural population of Muanza was low, considering the physical exhaustion during the performance of their activities. The diet is monotonous, low in fat and high in carbohydrates, and does not include vegetables or fruit. Luz, 2014, in his work on "Food consumption and working conditions in the manual cutting of sugarcane in the state of São Paulo" highlights the scarcity of studies with the population that works in sugarcane cutting, but recognizes the need to understand the nutritional and work aspects, to improve the protection of the workers and to prolong the time in the activity with health. It is necessary to adopt a diet that can provide energy for the work of the farm. The working conditions are not the best because they occur under average temperatures of approximately 30° C characteristic of that area of the Country in the summertime. "Among the information shared by the author,

the average annual temperature of 24.5 °C stands out. The author also announces that January is the warmest, with a maximum average temperature of 30 °C, while the month of July is the coldest, with a minimum average of 18 °C.” (Pacheco, 2009), which leads us to affirm that workers are subject to thermal stress since they are exposed to the sun for long periods, considering that the workday begins at five o'clock in the morning until approximately three hours of the afternoon. Abreu (2011), in his article on the production of sugarcane in Brazil and the health of the rural worker, describes similar working conditions to that of the workers at Muanza and in one of his conclusions affirms that excessive work hours, exposure to heat, inadequate food, unsafe transportation, financial devaluation, accident risks and psychological factors expressed in the form of discontent, stress and anxiety further aggravate the health of people working on sugarcane plantations. By making clear the precarious working conditions and the risks arising from field work, it is even worse if we are dealing with workers who do not have adequate food intake during work.

**Table 2.** Nutritional composition of tubers

Yam	Energy Kcal	Protein (%)	Carbohydrates (%)	Fats (%)	Ashes (%)	Fibres (%)	Ca (g)	Mg (g)	K (g)	P (g)
<i>Dioscorea cayennensis</i>	384	6.75	72.19	0.83	4.03	3.35	290	181	955.5	990
<i>Dioscorea rotundata</i>	385	7.5	70.49	0.78	5.17	2.3	0.25	212.5	1072	797.5

## CONCLUSIONS

The peasant's workers in Muanza district have a usual low energy intake that does not guarantee the replacement of spent energy during its activity. The *Dioscorea cayennensis* and *Dioscorea rotundata* tubers cooked together with high-fat foods such as dried peanuts, sesame seeds, pumpkin seeds and the inclusion of local fruits can provide the worker with a diet with higher energy value, which would help to supply the physical activity resulting from its activity reducing the risks of the work accidents and increasing health and well-being.

## References

- Adepoju, O. T. (2012). Effects of processing methods on nutrient retention and contribution of white yam (*Dioscorea rotundata*) products to nutritional intake of Nigerians. *African Journal of Food Science*, 6(6) 163-167.
- Adepoju, O. T. (2017). Nutrient and Antinutrient composition of yellow Yam (*Dioscorea cayennensis*) products. *ELSEVIER*, v11, pp. 428-431. [Consult.a 02.04.2019] Available on [https://www.researchgate.net/publication/313816778\\_Nutrient\\_and\\_antinutrient\\_composition\\_of\\_yellow\\_yam\\_Dioscorea\\_cayennensis\\_products](https://www.researchgate.net/publication/313816778_Nutrient_and_antinutrient_composition_of_yellow_yam_Dioscorea_cayennensis_products)
- De Abreu, D., De Moraes, L. A., Nascimento, E. N., & De Oliveira, R. A. (2011). A produção da cana-de-açúcar no Brasil e a saúde do trabalhador rural. *Revista Brasileira de Medicina do Trabalho*. v. 9, n. 2, p. 49-61. [Consult.a 04.04.2019] Available on <<http://hdl.handle.net/11449/72967>>
- Gomes, S. J. (2015). *Guia para uma alimentação saudável e ecológica*. Porto: UPorto Edições.
- Korkalo, L., Hauta-alus, H., & Mutanen, M. (2011). *Food composition tables for Mozambique*. University of Helsinki: Helsinki, Finland. [Consult.a 04.04.2019]. Available on <<https://ilsirf.org/wp-content/uploads/sites/5/2017/03/Mozambique2011FCT.pdf>>
- Luz, V. G., Zangirolani, L. T. O., Vilela, R. A. D. G., & Corrêa Filho, H. R. (2014). Food consumption and working conditions in manual sugarcane harvesting in Sao Paulo state. *Saúde e Sociedade*, 23(4), 1316-1328.

Mussagy, I. H. (2014). Poorest Districts of Sofala Province and the Agricultural Production. Beira, Sofala, Moçambique. [Consult.a 10.04.2019]. Available on [https://www.researchgate.net/publication/280113599\\_O\\_Nivel\\_de\\_Producao\\_Agricola\\_nos\\_Distritos\\_mais\\_Pobres\\_da\\_Provincia\\_de\\_Sofala\\_Poorest\\_Districts\\_of\\_Sofala\\_Province\\_and\\_the\\_Agricultural\\_Production](https://www.researchgate.net/publication/280113599_O_Nivel_de_Producao_Agricola_nos_Distritos_mais_Pobres_da_Provincia_de_Sofala_Poorest_Districts_of_Sofala_Province_and_the_Agricultural_Production)

Pacheco, J. A. A. Estratégias para sustentabilidade da flora bravia nas comunidades do distrito de Muanza, província de Sofala–Moçambique (Dissertação Mestrado, Universidade Estadual do Ceará, Centro de Ciências e Tecnologia, Fortaleza, 2009.117 p).

## The Posted Workers and their difficulties in European Union

Antonio Dickson Sobrinho<sup>1</sup>, Mário Vaz<sup>2</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT (up20171732@fe.up.pt) ORCID 0000-0003-4457-3081, <sup>2</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (gmavaz@fe.up.pt) ORCID 0000-0002-6347-9608  
[https://doi.org/10.24840/978-972-752-260-6\\_0056-0060](https://doi.org/10.24840/978-972-752-260-6_0056-0060)

### Abstract

**Introduction:** The present European Union (EU) society is divided into several economic classes that share the same goal and ensure their well-being through funds obtained from their work. Then, the man must perform work, independently or for his employer, and be economically compensated for it. For this reason, the man moves to regions where there is a demand for labor and preferably where it is well remunerated. We are dealing here with a special class of displaced workers, a population mostly made up of people with no greater qualifications or skills. These people need work to be able to guarantee their livelihood and that of their families. Having at work their only wealth these people seek to meet the need for EU mobility of workers becoming vulnerable to employers without respect for labor laws and Occupational Safety and Health (OSH) rules. It is important to know that a posted worker is an employee who is sent by his / her employer to work temporarily in another country to provide a cross-border service. This is not the same as a long-term mobile worker, who lives and works for an indefinite period in another Member State, or a cross-border worker, who lives in Member State A but works in Member State B. **Introduction:** Behind the designation of "displaced worker" there is a disregard of labor and economic legislation in many EU countries. **Methodology:** Systematic review in Science Direct and Web of Science databases, using Prisma P tool, and data Parliament and European Commission and EU-OSHA. **Results:** Research, studies, and articles point to disrespect by Unions, industry and entrepreneurs of Labor legislation, Occupational Safety and Health of Posted Workers. **Conclusion:** The analysis resulted in a very real picture of the condition of the worker posted in the EU. Better protection for several categories of workers were taken by the European Parliament: the new rules will apply to temporary agency workers and workers in chain posting to ensure also for them the principle of equal pay for equal work at the same place. Workers in non-genuine posting will be protected too. Member States will have 2 years to implement the new rules into their national legislation. They will then have to apply and start enforcing the rules.

**Keywords:** Temporary Work, Work conditions, Construction Industry.

### INTRODUCTION

In current EU legislation the movement of cross-border posted workers is seen as a smart and unique way of meeting the need to provide services where it is urgent in the context of freedom of movement for workers. Unfortunately the right to equal treatment has been only partially attended when comparing national citizens with citizens from other countries. The role and impact of this displacement for specific sectors as well as regions and countries are significant and are being discussed in the European Parliament (PWD-European Parliament, 2017). This work wanted to draw attention to a singular fact that is the exploitation of man by man himself or by the so-called consumer society. The main intention was to point out facts observed in the research that are of paramount importance for the safety and health of man. Workplaces of multiple employers, the result of the fragmentation of work and the outsourcing of most of the work to more specialized companies, creating a long chain of subcontracting in which there are native and foreign providers (Marchington et al., 2005). In the EU, many subcontractors post their workers from other EU countries under the Posting of Workers Directive (Directive 96/71 / European Commission (EC). This is often the case in the agriculture, meat industry, the marine industry, and the civil construction, the sector most benefiting from this action with 43.7% of the 1.92 million A1 documents issued in 2014 by the Member States declarants (Pacolet and De Wispelaere, 2015). The company filing involves only skilled workers (Pipers, Electricians, Welders, etc.). In addition, companies that receive the most displaced workers are generally large contractors, while the shipping companies are generally SMEs that provide services along the subcontracting chain (FGB and COWI, 2016; Idea Consultant Ecorys Netherlands, 2011; ISMERI Europa, 2012), showing total disregard for the conditions of the Posting of Workers Directive (Directive 96/71 / EC).

## METHODOLOGY

A systematic review with the theme "Posted Workers in U.E." was done, using quotes to restrict the objectives in the databases, Science Direct and Web of Science, using the Prisma P tool, and the Mendeley Manager. Eligibility criteria used: Time: 2015 to 2019; Document Type: Articles; Sources: Journals and Review Journals; Lingua: English and also the appropriate key words (KW). After collecting 44 articles related to its main theme, and applying the "eligibility criteria", excluding duplicities, a total of 10 articles were obtained (SD: 04 and WofS: 06). Also performed data search, together with government agencies (Parliament and the European Commission) and non-governmental organizations, EU-OSHA, to obtain official information, focusing on the posted worker, his workplace, Occupational Safety and Health (OSH) conditions and the inherent PWD legislation, which resulted in 03 documents to the theme. In addition, two more articles came from the transnational conference "Employment / Working Conditions, Occupational Safety and Health of the Posted Workers" in Ljubljana, (2017). This conference was of great importance to the EU as were discussed new and current challenges related to occupational health and safety (OSH), work and working conditions of workers. At the end of this search were obtained a total of 12 articles plus 03 documents from governmental organizations, to support this work.

## RESULTS

In the current European Union, the posting of workers has become a standard way for companies to reduce wage costs. Subcontracting is a fundamental feature in the restructuring of labor relations and has brought various changes between contingent and direct employment, and between contingent forms of labor (Forde et al., 2009), unequal terms and conditions among workers employed by different contractors (Lillie, 2012), lack of clarity about where to address complaints (Fudge, 2012, Marchington et al., 2005) and between workers and the employer(s). In general, there are two main "models" of posting: one driven by labor cost differentials, the other driven by scarcity and demand for skilled and highly skilled workers. Poland, Slovenia and Portugal send the majority of the posted workers, with respectively 124,472, 52,754 and 43,823 PDs A1, while the main destinations of the posted workers are Germany, France and Belgium, respectively receiving 131,066, 54,691, 53,601 PDs A1. In particular, Slovenia, Croatia, Hungary, Poland, the Czech Republic, Estonia, Lithuania and Portugal have specialized in sending workers to work in construction and this sector absorbs over half of Belgium, Luxembourg, Liechtenstein, Austria, Slovenia, Finland, Sweden and Latvia (Pacolet and De Wispelaere, 2015: 38-39). The survey has shown gross negligence in monitoring these flows of people due to the "proper use" of the posting of workers in violation of national and European regulations. On "proper use", construction employers benefit from these workers in reducing costs in social security contributions and taxes because there is a large difference between sending and receiving countries with variations of up to 25-30% of gross value (Bernaciak, 2015, Bernsen and Lillie, 2015, Cremers, 2011, Voss et al., 2016). Temporary workers are paid the minimum amount, instead of salaries in force in the countries of destination, without local or internal collective agreements, applied to those who work in national companies. Despite the lack of statistics on the real basic salaries of the workers mentioned, research has shown that IDPs earn less (between € 5-€ 8 / h) than local workers, particularly labor-intensive sectors such as construction, transportation, tourism, or care work (Berntsen and Lillie, 2015, Voss et al., 2016). In the Netherlands, the salaries of workers seconded to construction were sometimes below the universal minimum wage, documented trade unionists (FGB and COWI, 2016). Research by employers' organizations shows that in Denmark "posted

workers earn on average 10% to 15% less than local workers" (FGB and COWI, 2016: 81). A comparison between established and actual minimum wages shows that in Germany "the average gross hourly wage in the construction sector-17.11 euros (Federal Bureau of Statistics) -is 32% higher than the minimum wage for skilled workers and 56% higher than the minimum wage of unskilled workers in West Germany "(ISMERI, 2012: 43-44).

## DISCUSSION

The present research showed us different views that participants have from the same segment. So far, this work force has largely fallen outside the scope of the host country's trade union representation. High labor turnover, language barriers, and limited trade union resources hamper solidary relationships between trade unions and outreach workers (Wagner and Lillie, 2014). Krings (2009), in a comparative study within the EU highlights notable differences between the UK, Austria, Germany and Ireland, of how unions engage with migrant workers. Alho (2013) supports, emphasizing trade union strategies Finnish restrictions on workers. According to Andrijasevic (2015), there are two aspects to the discussion: the view of "social dumping", which considers the migration of labor unsettling to the industrial commitments existing in Western Europe; and the "integrationist" perspective, which sees migration beneficial to the prospects of economic growth. In the industrial view, according to supporters of the first strand, they identify the causes of social dumping in west-east industrial relocation and the east-west posting of workers (Caro et al., 2015). The difference in social patterns and wages results in a "bottom run", a downward pressure on social and living standards in the (old) EU-15. Associates of the second strand suggest that, despite popular anxieties about job displacement, the free mobility of Eastern European workers is beneficial to the EU-28 (current) (Bonin et al., 2008; Kahanec et al., 2010). The EU-15 needs a new workforce due to the aging of the population and filling jobs in a secondary market characterized by temporary contracts and lower wages. The labor migration, discovered in the case study at the Foxconn Electronics plants in the Czech Republic (Andrijasevic, 2015), is stimulated by the EU labor market perspectives and the subjective desires of migrant workers to create new and better social and economic opportunities. Construction workers who provide construction services mostly perform labor-intensive tasks and therefore need to work longer hours for lower wages than the receiving countries. Their health and safety are more likely to be at risk and receive no training. In many cases, outsourcing in construction involves a multilevel subcontracting system involving posted workers who come from different countries and therefore have difficulty communicating with each other at the construction site (Cremers, 2011; Idea Consult and Ecorys Netherlands, 2011; Ouali, 2012; Thörnqvist and Bernhardsson, 2015). These outworkers have little awareness of their rights, even for lack of union representation and isolation, in recipient countries (Wagner and Lillie, 2014). Clark (2012) pointed out issues in the Civil Construction sector in the United Kingdom, which is a local industry with an internationalized labor market, a contingent labor force and the largest number of temporary workers in the country. The research questions were: What are the health problems in multinational construction workplaces where part of the workforce is posted from other EU countries? How were these issues addressed in the UK? The workforce was made up of locally hired workers and postage (20%). The displaced were from Spain, Poland, Ireland, Slovenia and Slovakia. The projects operated under the National Agreement for the Engineering Construction Industry (NAECI), showing that there was agreement from the local authorities. He argued that working in a transnational and multiracial environment brought the temporary worker, incompatibility of skills and inadequate assignment of tasks, pointed out as factors of direct action for the health and safety in the workplace. He

emphasized that when performing their tasks, they expose themselves to several occupational health and safety risks. The level of exposure may be higher or lower depending on the level information and culture of this worker. Sargeant and Tucker (2009) proposed a framework of "layers of vulnerability" to identify OSH risks to migrant workers in general. They identified three sets of factors to be seen. - The first includes migration factors: migration status and the conditions of their recruitment. The second includes characteristics typical of migrant workers: socio-economic conditions in the country of origin, educational level and skills, and their language skills. - The third one identifies the conditions of the recipient country, ie characteristics of employment and the sector, access to collective representation, access to regulatory protection and particular problems of exclusion and social isolation. Industry accounts for 69.1% (including construction with 45%), services for 29.4% and agriculture and fisheries for 1.5% (European Commission, 2017). Over the past 20 years, the EU economy and labor market has evolved considerably, requiring a revision of legislation. Businesses take advantage of the difference in labor costs between EU countries, which can lead to unfair competition. According to the European Commission, posted workers can earn up to 50% less in some cases. By 2015, there were 2.05 million posted workers in the EU. Posting increased 41.3% between 2010 and 2015.

## CONCLUSIONS

Based on this picture, it is evident the different dimensions of migrant labor and how hard they are affected in the OHS vulnerabilities of the workers. The analysis of the articles made it possible to draw a very realistic, even cruel, picture of the circumstances that occur to the worker displaced in the EU, especially in the field of construction, where it is possible to detect mockery and disregard for all types of OSH legislation, Social and Labor, is of common use and commonplace. In summary, disrespect for decent working conditions is typical of large and small construction sites, requiring that there be an active inspection and exemplary penalty, by the authorities of the Government of the UE. The results of the study indicated as factors contrary to the safety and health of workers: Long and intense working days and hours extras were common in the workplace. Inter-linguistic communication also presented a challenge in terms of occupational health and safety issues. Better protection for several categories of workers were taken by the European Parliament: the new rules will apply to temporary agency workers and workers in chain posting to ensure also for them the principle of equal pay for equal work at the same place. Workers in non-genuine posting will be protected too. In 2017, 2.8 million posting operations took place in the EU. The EU average duration for such operations is less than 4 months. Given the short duration of most postings, when converted into full-time jobs this amounts only to 0.2% of total EU employment.

## References

- Alho R (2013) "Varieties of capitalism and translocal linkages shaping trade union strategy in the context of transnational labor mobility". *Nordic Journal of Working Life Studies* 3(3): 133–153.
- Altreiter, C., Fibich, T. and Flecker, J. (2015). "Capital and labour on the move: the dynamics of double transnational mobility". In: Drahokoupil, J. (ed.) *The outsourcing challenge. Organizing workers across fragmented production networks*. Brussels: ETUI.
- Andrijasevic, R, Sacchetto D, (2016) "From labour migration to labour mobility? The return of the multinational worker in Europe"; Vol. 22(2) 219–231; [sagepub.co.uk/ journals Permissions.nav](http://sagepub.co.uk/journalsPermissions.nav); DOI: 10.1177/1024258916635975

- Bonin H, Eichhorst W, Florman C, Hansen MO, Skio<sup>o</sup> Id L, Stuhler J, Tatsiramos K, Thomasen H and Zimmermann KF (2008) "Geographic Mobility in the European Union: Optimising Its Economic and Social Benefits". Institute for the Study of Labor, Research Report no.19.
- Berntsen, L. and Lillie, (2015). "Breaking the law? Varieties of social dumping in a Pan-European labour market". In: Bernaciak, M. (ed.) Market Expansion and Social Dumping in Europe. London: Routledge, pp. 43–60.
- Caro E, Berntsen L, Lillie N and Wagner I (2015) "Posted Migration and Segregation in the European Construction Sector". *Journal of Ethnic and Migration Studies* 41(10): 1600–1620.
- Clark, N. (2012). "Regulation and Enforcement of Posted Workers Employment Rights". Country Report: UK. Working Lives Research Institute.
- Cremers, J. (2010). "In search of cheap labour in Europe Working and living conditions of posted workers. Part 1 – Synthesis report" (Project VS/2009/0475). Brussels: European Federation of Building and Woodworkers.
- Cremers, J. (2011). "In search of cheap labour in Europe. Working and living conditions of posted workers". Brussels: European Federation of Building and Woodworkers, CLR.
- Fondazione Giacomo Brodolini, COWI (2016). "Study on wage setting systems and minimum rates of pay applicable to posted workers in accordance with Directive 96/71/EC in a selected number of Member States and sectors". Luxembourg: Publications Office of the European Union.
- Forde, C., MacKenzie, R., & Robinson, A. (2009). "Built on shifting sands: Changes in employers' use of contingent labour in the UK construction sector". *Journal of Industrial Relations*, 51(5), pp. 653–667.
- Fudge, J. (2012). "Precarious migrant status and precarious employment: The paradox of international rights for migrant workers". *Comp. Lab. L. & Pol'y J.*, 34, 95. Programme and Book of Proceedings 15
- Idea Consult and Ecorys Netherlands (2011). "Study on the economic and social effects associated with the phenomenon of posting of workers in the European Union". Brussels: European Commission. [ec.europa.eu/social/BlobServlet?docId=6678&langId=en](http://ec.europa.eu/social/BlobServlet?docId=6678&langId=en) (accessed 10 Mar 2017)
- ISMERI Europa (2012). "Preparatory study for an impact assessment concerning the possible revision of the legislative framework on the posting of workers in the context of the provision of services. Final report". Brussels: European Commission. [ec.europa.eu/social/BlobServlet?docId=7511&langId=en](http://ec.europa.eu/social/BlobServlet?docId=7511&langId=en) (last accessed 10 Mar 2017)
- Kahanec M, Zaiceva A and Zimmermann KF (2010) Lessons from migration after EU enlargement. In: Kahanec M and Zimmermann KF (eds) *EU Labor Markets After Post-Enlargement Migration*. Berlin: Springer Verlag, pp. 3–46
- Krings T (2009) A race to the bottom? Trade unions, EU enlargement and the free movement of labour. *European Journal of Industrial Relations* 15(1): 49–69.
- Lillie, N. (2012). "Subcontracting, posted migrants and labour market segmentation in Finland". *British Journal of Industrial Relations*, 50(1), pp. 148–167.
- Marchington, M. (2005). "Fragmenting work: Blurring organizational boundaries and disordering hierarchies". Oxford University Press
- National Joint Council (2008) NJC "Guide to Health, Safety and Welfare". Available at [http://www.njceci.org.uk/publication/download-the-njc-guide-to-health-safetywelfare-in-pdf-format-free-of-charge/wppa\\_open/](http://www.njceci.org.uk/publication/download-the-njc-guide-to-health-safetywelfare-in-pdf-format-free-of-charge/wppa_open/) (last accessed 16 June 2017)
- Ouali, N. (2012). "Regulation and Enforcement of Posted Workers Employment Rights (PostER). Belgian Case Study Final Report". Brussels: ULB. Programme and Book of Proceedings. 21
- Pacolet, J., De Wispelaere, F. (2015). "Posting of workers Report on A1 portable documents issued in 2014". Brussels: European Commission. [ec.europa.eu/social/BlobServlet?docId=15348&langId=en](http://ec.europa.eu/social/BlobServlet?docId=15348&langId=en) (last accessed 10 Mar 2017)
- Sargeant, M., & Tucker, E. (2009). "Layers of vulnerability in occupational safety and health for migrant workers: case studies from Canada and the UK". *Policy and practice in health and safety*, 7(2), pp. 51–73
- Thörnqvist, C. and Bernhardsson, S. (2015). "Their own stories – how Polish construction workers posted to Sweden experience their job situation, or resistance versus life projects". *Transfer* 21(1): pp. 23–36.
- Voss, E., Faioli, M., Lhernould, J.P., Iudicone, F. (2016). "Posting of Workers Directive – current situation and challenges". Brussels: European Parliament.
- Wagner, I. and Lillie, N. (2014). "European Integration and the Disembedding of Labour Market Regulation: Transnational Labour Relations at the European Central Bank Construction Site". *Journal of Common Market Studies* 52(2): pp. 403–419.



## Food in the occupational environment and its benefits in worker's health

Pablo Monteiro Pereira<sup>1</sup>, J. Duarte<sup>2</sup>, Olívia Pinho<sup>3</sup>, J. Santos Baptista<sup>4</sup>, João Ferraz<sup>5</sup>, Amanda Santana<sup>6</sup>

<sup>1</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (pablomonpe@hotmail.com) ORCID 0000-0002-1586-0359, <sup>2</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (jasduarte@fe.up.pt) ORCID 0000-0002-5856-5317, <sup>3</sup>REQUIMTE, Faculty of Nutrition and Food Science, University of Porto, PT, (oliviapinho@fcna.up.pt) ORCID 0000-0001-9477-8638, <sup>4</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (jsbap@fe.up.pt) ORCID 0000-0002-8524-5503, <sup>5</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (ferraz.jhm@gmail.com) ORCID 0000-0002-2381-7975, <sup>6</sup>Estácio de Sá University (c.amandasantana@gmail.com) ORCID 0000-0002-6269-1236  
[https://doi.org/10.24840/978-972-752-260-6\\_0061-0067](https://doi.org/10.24840/978-972-752-260-6_0061-0067)

### Abstract

**Introduction:** The food universe is very broad and has a lot to do with the culture of each region. However, the macronutrients' constitution: proteins, carbohydrates, and lipids can be adjusted in any diet, thus allowing food to be a way to promote health and quality of life and to lower the risk of work accidents by improving sleep quality. **Objective:** To amplify and update a non-labor diet application, aiming to indicate, among the existing diets, the one that allows greater work capacity, better performance and more health through the metabolic control. **Methodology:** The PRISMA methodology was applied in the bibliographic review. Scientific articles, indexed in international journals were searched in the following databases: Medline (searched via PMC – PUBMED Central) and Scopus and through JISSN. Using the keywords diets, "position stand", timing, nutrients, work performance, sleep, consensus and protein, combined three by three, as well as their respective variations. **Results and discussion:** 247 articles were found. After applying the eligibility criteria, only articles published in the last 5 years in journals, cross-sectional studies (in humans) with consent, and published in English were accepted. Duplicate articles were removed. Articles which were not related to the theme were excluded after reading the title and abstract, excluding 206 papers. In this study were included 41 papers. Out of the 41, 13 articles were added by cross-reference. In the MEDLINE search, the [SECT] filters - referring to the research section and [TW] were inserted for words present in the articles when searching composite words. Initially, the compositions of the several diets were addressed: Hypocaloric - LED and VLED, Low Fat - LFD, Low Carbohydrate - LCD, Ketogenic - KD, and Hypercaloric - HPD. Their main strengths and their main characteristics were fully addressed. **Conclusion:** It was concluded that the HPD, from all the diets, was the one that had the greatest practical relevance in work environment, once its results in the maintenance of a lean body mass, through its high ingestion frequency. The improvement of the health markers and the nocturnal vigil period reduction, reveal the effectiveness in improving working performance.

**Keywords:** Diet, Stand position, Work performance, Nutrient, Sleep, Protein.

### INTRODUCTION

The nutritional universe is very broad and, for this reason, it allows carrying out its analysis through different perspectives. The discussion about diets and their respective compositions is relevant to health science insofar it revises concepts addressed in different areas, thus contributing to a multidisciplinary discussion. Regarding the sports field, nutrition has daily updates and, therefore, is discussed thoroughly (Jäger et al. 2017). However, concerning the occupational environment that is not the case. Therefore, this demonstrates the relevance of nutrition studies focused on the occupational environment, since adequate nutrition is able to improve the worker's quality of life, generating positive effects with changes throughout the system (Anderson, Gallagher, and Ramirez Ritchie 2018). Many relationships between diet and sleep are currently being addressed, generating new adjustment needs by companies interested in improving their productivity indexes (Schmitt, Belschak, and Den Hartog 2017; Lindseth, Lindseth, and Thompson 2013). Thus, companies with greater nutritional awareness are able not only to provide a better quality of life to the worker but also to achieve higher productivity and decreasing absenteeism due to musculoskeletal disorders. The present work focuses on the assessment of the nutritional compositions of the existing diets presented in the "position stands" of the Journal of the International Society of Sports Nutrition (JISSN) and tries to correlate them to the occupational environment, allowing better diet choices. The paper objective is to amplify and update the applicability of diet in the occupational environment, in order to indicate, among the existing diets, the one that presents in its constitution the best

relation between the maintenance of the worker's body composition, the improvement of its performance and the promotion of health through metabolic control.

## METHODOLOGY

The paper methodology is based on the scoping review (Grant and Booth 2009; Peters et al. 2015), through the analysis of scientific articles indexed in international journals published by Medline (via PUBMED CENTRAL) and Scopus and JISSN using, for that, the PRISMA Statement guidelines (Shamseer et al. 2015; Moher et al. 2009; Tricco et al. 2018; Liberati et al. 2009). The used keywords were “diets”, “position stand”, “timing”, “nutrients”, “work performance”, “sleep”, consensus and protein, combined three by three, as well as their respective variations.

## RESULTS AND DISCUSSION

In the initial research, 247 papers were found. After applying the eligibility criteria papers articles published between 2013 and 2018, review papers, articles published in journals, cross-sectional studies (in humans) with consent, and published in English were accepted. Articles which did not comply with the theme were excluded after reading the title and abstract, excluding 206 papers. In this study were included 41 papers, after using the snowballing technique (Wohlin and Claes 2014). In MEDLINE, the filters [SECT] (referring to the research section) and [TW] (regarding paper keywords) were used. In general, the human body, performing its daily activities (that is, without practicing any additional physical activity), needs between 2.0 and 2.5 Kcal per day (Evers et al. 1995). On the other hand, individuals who practice physical activity daily and, therefore, end up increasing the muscle mass will present an increase of the metabolic rate, demanding a greater daily caloric intake (Periasamy, Herrera, and Reis 2017). When assessing the context of food intake frequency in the occupational environment, the meals provided to the workers must be adjusted in order to promote health, control weight gain, improve metabolic blood markers results, especially LDL cholesterol, total cholesterol and insulin and to promote the maintenance of muscle mass in the body composition (Kerksick et al. 2017). It is of utmost importance to analyze the task regarding its intensity, to provide the worker with meals with the right amount of calories (Jäger et al. 2017). The current protocols published in JISSN by La Bounty et al (2011) describe that the frequency of the meals must be, at least, more than 3 times a day, which is considered standard in the industrialized world, and, if associated with the practice of daily physical activity, can provide very favorable responses to worker health (Fontana et al. 2004). Firstly, it is important to understand that the increase in daily food frequency does not alter the body composition of sedentary people (Garaulet et al. 2013; Jakubowicz et al., 2012, 2013). In contrast, when the population is physically active, good results are observed in all health markers (Garaulet et al. 2013; Gudzone et al. 2013; Parry and Straker 2013; Wooding et al. 2017; Buckner, Loenneke, and Loprinzi 2018). Studies from 2008 onwards confirm that the glycemia and insulin indexes decrease with increasing food frequency since the calorie supply at each meal is lower. Thus, avoiding the hypercaloric intake per meal improves the metabolic controls related to the circadian cycle (Smeets and Westerterp-Plantenga 2008; Jakubowicz et al. 2012; Garaulet et al. 2013). In addition to that, the increase of the frequency of the meals acts in the stomach distension and in the regulation of the gastric hormones promoting satiety and control of the hunger (Speechly and Buffenstein 1999; Smeets and Westerterp-Plantenga 2008; Leidy and Campbell 2011; Lin et al. 2015; Versteeg et al. 2018). The nutritional composition, acting as a crucial point of the dietary approach, is of supreme importance for the success of the objectives of improving quality of life, health and well-being. Hence, according to the nutrients and their concentrations, it is important to distinguish

different dietary directions, that is, diets, so that, after identifying their strengths and limitations, it is possible to choose the one that best suits the context of the occupational environment.

- Very Low Energy Diet (VLED) and Low Energy Diet (LED) are attributed, in general, to low-calorie diets, with LED diets with 800-1200 Kcal per day and VLED diets with 400-800Kcal per day. VLED, in the nutritional context, are made to compensate for two meals a day and are supported by 70-100g per day of protein, 15g per day of fats, and 30-80g per day of carbohydrates. Despite being a diet reported in the literature, it presents many side effects to the individuals who do it, such as cold intolerance, fatigue, dizziness, headache, and intestinal constipation and has no long-term effectiveness (Aragon et al. 2017). Therefore, it does not fit the purpose of diets in occupational settings.
- Low Fat Diet (LFD) contains about 20-35% fat in the total calories eaten per day (Aragon et al. 2017). A variation of this diet is called Very Low Fat Diet (VLFD) with 10-15% fat in total nutrient composition, although its nomenclature is based on the Acceptable Macronutrient Distribution Ranges (AMDR) for adults, established by the Food and Nutrition Board for the Institute of Medicine (Manore 2005). This diet should be called a diet with hypercarbohydrates because it is presented by AMDR with 10-15% of protein, 45-65% of carbohydrates and 20-35% of fat.
- Low Carbohydrate Diet (LCD) can be considered the most widespread diet in society. In 2016, Hashimoto et al. described that any diet with a  $\leq 40\%$  carbohydrate value should be considered as an LCD (Hashimoto et al. 2016), being this value used as a reference in the protocol approached by JISSN. Although this diet has the strongest availability of food on the market, as there are not many restrictions regarding foods high in fat and low in carbohydrates, it is not possible to say, in the long run, that LCD diets are effective in the maintenance of body composition, with loss of mass relatively equal to others. A study comparing LCD with LFD showed no relevant difference in the individuals' body composition, is believed that the difference presented occurred due to the higher protein content in the LCD than in the LFD, therefore, the LCD diets did not prove to be beneficial over time (Gardner et al. 2007; Hu et al. 2012).
- Ketogenic Diet (KD) has less than 10% carbohydrate in its composition (Westman et al. 2007). Depending on the diet protein concentration, the KD comprises the ingestion of 60-80% of fat. The concept of weight loss because of KD does not only occur due to the low carbohydrate intake. In fact, it is believed that the metabolic stress generated by fat oxidation through lipolysis is the main mechanism responsible for weight loss (Aragon et al. 2017). On the other hand, Soenen et al.(2012) described that the effect of weight loss occurs due to the concentrations of proteins absorbed in the diet rather than the low carbohydrate ratio (Soenen et al. 2012), confirmed by the study of Weigle et al. (Weigle et al. 2005). However, a common negative point pointed out by KD studies is the difficulty of the body's metabolic adaptation to ketogenic feeding (Burke 2015). Another disadvantage is the fact that there is a lack of superior effects on body composition compared to other diets that maintain the same amount of protein and calories involved (Burke et al. 2017).

- High Protein Diet (HPD) is defined as a diet that promotes ingestion  $\geq 25\%$  protein (Makris and Foster 2011). Previous studies described that the daily dose absorbed by an individual was 1.2-1.6g per kg body weight (Leidy et al. 2015). A prospective, randomized, parallel and single-blind group study by Longland et al. (2016) with 40 participants, 20 per group who completed 4 weeks of intense training, with a 40% hypoenergetic diet, 33 kcal per day for lean body mass. The two groups were divided: the control group (CON) received 1.2g of protein in the diet per kg of body weight day (1.2g /kg/day), and the other group received 2.4g /kg/day (PRO), in which the two groups performed the same types of training combined with anaerobic and high resistance exercise during that period. Results showed that the PRO group, which consumed 2.4g / kg / day of protein, had an increase in muscle mass of 1.2 kg and a loss of fat mass of 4.8 kg, while the CON group with ingestion of 1.2 g /kg/day presented preservation of muscle mass by 0.1 kg and a loss of fat mass by 3.5 kg (Longland et al. 2016).

Antonio et al. (2014, 2015, 2016) concluded that that the supply of higher doses (than the usual doses of proteins), such as 4.4g per kg and 3.6g per kg is beneficial to muscle mass gain and mass loss. This suggests that the effect of the extra-consumed protein would act as a higher thermal effect of the feed, thus increasing the thermogenesis of non-exercise activity, the thermal effect of exercise, and also the excretion of faecal energy and reduced intake of the other macronutrients, via increased satiety and suppression of hepatic lipogenesis. The conclusions provided by Antonio et al. (2014, 2015, 2016) suggest that the known effects of temperature, satiety and muscle mass related to HPD can be amplified in trained individuals submitted to progressive resistance exercises. However, studies report that protein is an expensive nutrient to be introduced into the diet, a fact that reveals the downside of this diet.

## CONCLUSIONS

Considering the dimensional reality of a company, diet is a measure that promotes a benefit to both the employer and the employee. As demonstrated, the adequate choice of the nutritional composition offered daily to the worker provides the maintenance of his muscular mass, reducing the muscular injuries and when, above all, combined with the physical activity. In addition, the adequate frequency of food intake (greater than 5 times a day) by means of meals offered by the employer, especially in those situations in which workers perform 12-hour shifts, promotes the improvement of their health markers. Results such as reduced systemic arterial pressure, lower LDL cholesterol, lower the glycemic indexes, reduced serum insulin release, muscle mass maintenance, and professionals' weight control can be observed. Thus, although all diets have strengths and limitations, it was verified that diets with the highest protein concentration (above 25% in the total composition of a diet), present greater benefits to the human being, especially to the worker. Their performance can be empowered due to the decrease in the nighttime wakefulness, thus justifying the maintenance and adaptation of the diet provided in the companies so that doses between 1.2-2.4g of protein per kg of weight per person daily (1.2-2.4 g /kg/day).

## References

Anderson, Michael L., Justin Gallagher, and Elizabeth Ramirez Ritchie. 2018. "School Meal Quality and Academic Performance." *Journal of Public Economics* 168 (December): 81–93. <https://doi.org/10.1016/j.jpubeco.2018.09.013>.

Antonio, Jose, Anya Ellerbroek, Tobin Silver, Steve Orris, Max Scheiner, Adriana Gonzalez, and Corey A. Peacock. 2015. "A High Protein Diet (3.4 g/Kg/d) Combined with a Heavy Resistance Training Program Improves Body Composition in Healthy Trained Men and Women--a Follow-up Investigation." *Journal of the International Society of Sports Nutrition* 12 (1): 39. <https://doi.org/10.1186/s12970-015-0100-0>.

Antonio, Jose, Anya Ellerbroek, Tobin Silver, Leonel Vargas, Armando Tamayo, Richard Buehn, and Corey A. Peacock. 2016. "A High Protein Diet Has No Harmful Effects: A One-Year Crossover Study in Resistance-Trained Males." *Journal of Nutrition and Metabolism* 2016: 9104792. <https://doi.org/10.1155/2016/9104792>.

Antonio, Jose, Corey A. C.A. Peacock, Anya Ellerbroek, Brandon Fromhoff, and Tobin Silver. 2014. "The Effects of Consuming a High Protein Diet (4.4 g/Kg/d) on Body Composition in Resistance-Trained Individuals." *Journal of the International Society of Sports Nutrition* 11 (1): 19. <https://doi.org/10.1186/1550-2783-11-19>.

Aragon, Alan A, Brad J Schoenfeld, Robert Wildman, Susan Kleiner, Trisha VanDusseldorp, Lem Taylor, Conrad P Earnest, et al. 2017. "International Society of Sports Nutrition Position Stand: Diets and Body Composition." *Journal of the International Society of Sports Nutrition* 14 (1): 16. <https://doi.org/10.1186/s12970-017-0174-y>.

Bounty, Paul M. La, Bill I. Campbell, Jacob Wilson, Elfego Galvan, John Berardi, Susan M. Kleiner, Richard B. Kreider, et al. 2011. "International Society of Sports Nutrition Position Stand: Meal Frequency." *Journal of the International Society of Sports Nutrition* 8: 1–12. <https://doi.org/10.1186/1550-2783-8-4>.

Buckner, Samuel L., Jeremy P. Loenneke, and Paul D. Loprinzi. 2018. "Protein Timing during the Day and Its Relevance for Muscle Strength and Lean Mass." *Clinical Physiology and Functional Imaging* 38 (2): 332–37. <https://doi.org/10.1111/cpf.12440>.

Burke, Louise M. 2015. "Re-Examining High-Fat Diets for Sports Performance: Did We Call the 'Nail in the Coffin' Too Soon?" *Sports Medicine* 45 (S1): 33–49. <https://doi.org/10.1007/s40279-015-0393-9>.

Burke, Louise M., Megan L. Ross, Laura A. Garvican-Lewis, Marijke Welvaert, Ida A. Heikura, Sara G. Forbes, Joanne G. Mirtschin, et al. 2017. "Low Carbohydrate, High Fat Diet Impairs Exercise Economy and Negates the Performance Benefit from Intensified Training in Elite Race Walkers." *Journal of Physiology* 595 (9): 2785–2807. <https://doi.org/10.1113/JP273230>.

Evers, C. L., J. Gullett, J. Parenteau, and D. Allaway. 1995. "The Food Guide Pyramid Choice System in Oregon Elementary School Cafeterias." *Journal of the American Dietetic Association* 95 (9 SUPPL.): A47. [https://doi.org/10.1016/S0002-8223\(95\)00507-2](https://doi.org/10.1016/S0002-8223(95)00507-2).

Fontana, L., T. E. Meyer, S. Klein, and J. O. Holloszy. 2004. "Long-Term Calorie Restriction Is Highly Effective in Reducing the Risk for Atherosclerosis in Humans." *Proceedings of the National Academy of Sciences* 101 (17): 6659–63. <https://doi.org/10.1073/pnas.0308291101>.

Garaulet, M, P Gómez-Abellán, JJ Alburquerque-Béjar, Y-C Lee, J M Ordovás, and F A J L Scheer. 2013. "Timing of Food Intake Predicts Weight Loss Effectiveness" 37 (4). <https://doi.org/10.1038/ijo.2012.229>.

Gardner, Christopher D., Alexandre Kiazand, Sofiya Alhassan, Soowon Kim, Randall S. Stafford, Raymond R. Balise, Helena C. Kraemer, and Abby C. King. 2007. "Comparison of the Atkins, Zone, Ornish, and LEARN Diets for Change in Weight and Related Risk Factors Among Overweight Premenopausal Women." *JAMA* 297 (9): 969. <https://doi.org/10.1001/jama.297.9.969>.

Grant, Maria J., and Andrew Booth. 2009. "A Typology of Reviews: An Analysis of 14 Review Types and Associated Methodologies." *Health Information & Libraries Journal* 26 (2): 91–108. <https://doi.org/10.1111/j.1471-1842.2009.00848.x>.

Gudzune, Kimberly, Susan Hutfless, Nisa Maruthur, Renee Wilson, and Jodi Segal. 2013. "Strategies to Prevent Weight Gain in Workplace and College Settings: A Systematic Review." *Preventive Medicine* 57 (4): 268–77. <https://doi.org/10.1016/J.YPMED.2013.03.004>.

Hashimoto, Y., T. Fukuda, C. Oyabu, M. Tanaka, M. Asano, M. Yamazaki, and M. Fukui. 2016. "Impact of Low-Carbohydrate Diet on Body Composition: Meta-Analysis of Randomized Controlled Studies." *Obesity Reviews* 17 (6): 499–509. <https://doi.org/10.1111/obr.12405>.

Hu, Tian, Katherine T. Mills, Lu Yao, Kathryn Demanelis, Mohamed Eloustaz, William S. Yancy, Tanika N. Kelly, Jiang He, and Lydia A. Bazzano. 2012. "Effects of Low-Carbohydrate Diets Versus Low-Fat Diets on Metabolic Risk Factors:

A Meta-Analysis of Randomized Controlled Clinical Trials.” *American Journal of Epidemiology* 176 (suppl\_7): S44–54. <https://doi.org/10.1093/aje/kws264>.

Jäger, Ralf, Chad M Kerksick, Bill I Campbell, Paul J Cribb, Shawn D Wells, Tim M Skwiat, Martin Purpura, et al. 2017. “International Society of Sports Nutrition Position Stand: Protein and Exercise.” *Journal of the International Society of Sports Nutrition* 14: 20. <https://doi.org/10.1186/s12970-017-0177-8>.

Jakubowicz, Daniela, Maayan Barnea, Julio Wainstein, and Oren Froy. 2013. “High Caloric Intake at Breakfast vs. Dinner Differentially Influences Weight Loss of Overweight and Obese Women.” *Obesity* 21 (12): 2504–12. <https://doi.org/10.1002/oby.20460>.

Jakubowicz, Daniela, Oren Froy, Julio Wainstein, and Mona Boaz. 2012. “Meal Timing and Composition Influence Ghrelin Levels, Appetite Scores and Weight Loss Maintenance in Overweight and Obese Adults.” *Steroids* 77 (4): 323–31. <https://doi.org/10.1016/J.STEROIDS.2011.12.006>.

Kerksick, Chad M., Shawn Arent, Brad J. Schoenfeld, Jeffrey R. Stout, Bill Campbell, Colin D. Wilborn, Lem Taylor, et al. 2017. “International Society of Sports Nutrition Position Stand: Nutrient Timing.” *Journal of the International Society of Sports Nutrition* 14 (1): 1–21. <https://doi.org/10.1186/s12970-017-0189-4>.

Leidy, Heather J., and Wayne W. Campbell. 2011. “The Effect of Eating Frequency on Appetite Control and Food Intake: Brief Synopsis of Controlled Feeding Studies.” *The Journal of Nutrition* 141 (1): 154–57. <https://doi.org/10.3945/jn.109.114389>.

Leidy, Heather J., Peter M. Clifton, Arne Astrup, Thomas P. Wycherley, Margriet S. Westerterp-Plantenga, Natalie D. Luscombe-Marsh, Stephen C. Woods, and Richard D. Mattes. 2015. “The Role of Protein in Weight Loss and Maintenance.” *American Journal of Clinical Nutrition* 101 (6): 1320S–1329S. <https://doi.org/10.3945/ajcn.114.084038>.

Liberati, Alessandro, Douglas G. Altman, Jennifer Tetzlaff, Cynthia Mulrow, Peter C. Gøtzsche, John P.A. Ioannidis, Mike Clarke, P.J. Devereaux, Jos Kleijnen, and David Moher. 2009. “The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration.” *Journal of Clinical Epidemiology* 62 (10): e1–34. <https://doi.org/10.1016/J.JCLINEPI.2009.06.006>.

Lin, Tin Chi, Theodore K. Courtney, David A. Lombardi, and Santosh K. Verma. 2015. “Association between Sedentary Work and BMI in a U.S. National Longitudinal Survey.” *American Journal of Preventive Medicine* 49 (6): e117–23. <https://doi.org/10.1016/j.amepre.2015.07.024>.

Lindseth, Glenda, Paul Lindseth, and Mark Thompson. 2013. “Nutritional Effects on Sleep.” *Western Journal of Nursing Research* 35 (4): 497–513. <https://doi.org/10.1177/0193945911416379>.

Longland, Thomas M, Sara Y Oikawa, Cameron J Mitchell, Michaela C Devries, and Stuart M Phillips. 2016. “Higher Compared with Lower Dietary Protein during an Energy Deficit Combined with Intense Exercise Promotes Greater Lean Mass Gain and Fat Mass Loss: A Randomized Trial.” *The American Journal of Clinical Nutrition* 103 (3): 738–46. <https://doi.org/10.3945/ajcn.115.119339>.

Makris, Angela, and Gary D. Foster. 2011. “Dietary Approaches to the Treatment of Obesity.” *Psychiatric Clinics of North America* 34 (4): 813–27. <https://doi.org/10.1016/j.psc.2011.08.004>.

Manore, Melinda M. 2005. “Exercise and the Institute of Medicine Recommendations for Nutrition.” *Current Sports Medicine Reports* 4 (4): 193–98. <http://www.ncbi.nlm.nih.gov/pubmed/16004827>.

Moher, David, Alessandro Liberati, Jennifer Tetzlaff, Douglas G. Altman, and The PRISMA Group. 2009. “Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement.” *PLoS Medicine* 6 (7): e1000097. <https://doi.org/10.1371/journal.pmed.1000097>.

Parry, Sharon, and Leon Straker. 2013. “The Contribution of Office Work to Sedentary Behaviour Associated Risk.” *BMC Public Health* 13 (1): 296. <https://doi.org/10.1186/1471-2458-13-296>.

Periasamy, Muthu, Jose Luis Herrera, and Felipe C.G. Reis. 2017. “Skeletal Muscle Thermogenesis and Its Role in Whole Body Energy Metabolism.” *Diabetes and Metabolism Journal* 41 (5): 327–36. <https://doi.org/10.4093/dmj.2017.41.5.327>.

- Peters, Micah D.J., Christina M. Godfrey, Hanan Khalil, Patricia McInerney, Deborah Parker, and Cassia Baldini Soares. 2015. "Guidance for Conducting Systematic Scoping Reviews." *International Journal of Evidence-Based Healthcare* 13 (3): 141–46. <https://doi.org/10.1097/XEB.0000000000000050>.
- Schmitt, Antje, Frank D. Belschak, and Deanne N. Den Hartog. 2017. "Feeling Vital after a Good Night's Sleep: The Interplay of Energetic Resources and Self-Efficacy for Daily Proactivity." *Journal of Occupational Health Psychology* 22 (4): 443–54. <https://doi.org/10.1037/ocp0000041>.
- Shamseer, Larissa, David Moher, Mike Clarke, Davina Ghersi, Alessandro Liberati, Mark Petticrew, Paul Shekelle, Lesley A Stewart, and PRISMA-P Group. 2015. "Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015: Elaboration and Explanation." *BMJ (Clinical Research Ed.)* 350 (January): g7647. <https://doi.org/10.1136/bmj.g7647>.
- Smeets, Astrid J., and Margriet S. Westerterp-Plantenga. 2008. "Acute Effects on Metabolism and Appetite Profile of One Meal Difference in the Lower Range of Meal Frequency." *British Journal of Nutrition* 99 (06): 1316–21. <https://doi.org/10.1017/S0007114507877646>.
- Soenen, Stijn, Alberto G. Bonomi, Sofie G.T. Lemmens, Jolande Scholte, Myriam A.M.A. Thijssen, Frank van Berkum, and Margriet S. Westerterp-Plantenga. 2012. "Relatively High-Protein or 'Low-Carb' Energy-Restricted Diets for Body Weight Loss and Body Weight Maintenance?" *Physiology & Behavior* 107 (3): 374–80. <https://doi.org/10.1016/j.physbeh.2012.08.004>.
- Speechly, D. P., and R. Buffenstein. 1999. "Greater Appetite Control Associated with an Increased Frequency of Eating in Lean Males." *Appetite* 33 (3): 285–97. <https://doi.org/10.1006/appe.1999.0265>.
- Tricco, Andrea C., Erin Lillie, Wasifa Zarin, Kelly K. O'Brien, Heather Colquhoun, Danielle Levac, David Moher, et al. 2018. "PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation." *Annals of Internal Medicine* 169 (7): 467–73. <https://doi.org/10.7326/M18-0850>.
- Versteeg, R. I., M. T. Ackermans, A. J. Nederveen, E. Fliers, M. J. Serlie, and S. E. La Fleur. 2018. "Meal Timing Effects on Insulin Sensitivity and Intrahepatic Triglycerides during Weight Loss." *International Journal of Obesity* 42 (2): 156–62. <https://doi.org/10.1038/ijo.2017.199>.
- Weigle, David S, Patricia A Breen, Colleen C Matthys, Holly S Callahan, Kaatje E Meeuws, Verna R Burden, and Jonathan Q Purnell. 2005. "A High-Protein Diet Induces Sustained Reductions in Appetite, Ad Libitum Caloric Intake, and Body Weight despite Compensatory Changes in Diurnal Plasma Leptin and Ghrelin Concentrations." *The American Journal of Clinical Nutrition* 82 (1): 41–48. <http://www.ncbi.nlm.nih.gov/pubmed/16002798>.
- Westman, Eric C, Richard D Feinman, John C Mavropoulos, Mary C Vernon, Jeff S Volek, James A Wortman, William S Yancy, and Stephen D Phinney. 2007. "Low-Carbohydrate Nutrition and Metabolism." *The American Journal of Clinical Nutrition* 86 (2): 276–84. <http://www.ncbi.nlm.nih.gov/pubmed/17684196>.
- Wohlin, Claes, and Claes. 2014. "Guidelines for Snowballing in Systematic Literature Studies and a Replication in Software Engineering." In *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering - EASE '14*, 1–10. New York, New York, USA: ACM Press. <https://doi.org/10.1145/2601248.2601268>.
- Wooding, Denise J., Jeff E. Packer, Hiroyuki Kato, Daniel W.D. West, Glenda Courtney-Martin, Paul B. Pencharz, and Daniel R. Moore. 2017. "Increased Protein Requirements in Female Athletes after Variable-Intensity Exercise." *Medicine and Science in Sports and Exercise* 49 (11): 2297–2304. <https://doi.org/10.1249/MSS.0000000000001366>.

# Specific Risks associated with the Manufacture of Airplanes

Niels Bumann

Faculty of Engineering, University of Porto, PT (up201803664@fe.up.pt) ORCID: 0000-0002-5665-6063  
[https://doi.org/10.24840/978-972-752-260-6\\_0068-0072](https://doi.org/10.24840/978-972-752-260-6_0068-0072)

## Abstract

**Introduction:** The aviation industry is growing fast, Boeing and Airbus are the biggest manufacturers in this area. The production and manufacture in the Aviation sector contain specific risks and hazards especially according to the size of the different parts of the airplane. This paper reviews and summarizes some special risks about this production chain, based on the manufacture line of an airbus aircraft. **Methodology:** The methodology used for this paper is a literature research. Different journal databases and library catalogues have been searched. Qualitative and quantitative studies have been included. **Results and Discussion:** Production of aircrafts dangles multiple dangers. The specific risks are mostly according to the size of the parts of the airplane, also the scale and level of the different operations are very complex. One big risk factor in the production of an Airbus airplane, is transportation. Airbus produces its parts all over Europe. The transportation to different locations is complicated and executed by different vehicles, ranged from special trucks to Beluga airplanes. To be highlighted here are the wings, which are produced in the United Kingdom and have to be maneuvered through small towns and streets, which are not designed to carry these big transports. This action contains multiple dangers, for the traffic, for the infrastructure and for the people involved in this process. Another specific risk, associated with the manufacture of an airplane is the size of the whole production area. In the size of small towns with big buildings to store and contain all parts of the airplanes, risks and dangers can fast be overlooked. Due to the size of the parts, many operations must be performed at great height. Operators face the risks of falling down the structure or dropping tools onto other people. The fact, that even a small risk that has not been adequately addressed poses a danger to hundreds of people who could later crash in this aircraft, highlights the aircraft industry of others. **Conclusions** Problems in this area are known, lots of different approaches were made in the past to identify all the risks and dangers, from the detailed approach of checking and analysing every single part, to the approach of including the bigger picture, containing risk scores based on ubiquity and geopolitical risks as well as ERP approaches in the whole manufacturing process.

**Keywords:** Aviation, Manufacture, Transportation, Aircraft, Airplane.

## INTRODUCTION

The Aviation sector is growing rapidly. Aircraft production has increased significantly in recent years and decades. Airbus alone has recorded a 28 percent increase in deliveries over the past five years. This means a number of approximately 800 deliveries in 2018, as shown in Figure 1. These statistics also mean that production has increased in recent years (Airbus). The question of risks and dangers arises. The manufacture of airplanes is a special production sector with various risks. The workers and people that are involved in the production process are exposed to dangers, which occur not exclusively, but specifically here. Next to the risks that the people are exposed to, also the infrastructure and other aspects are exposed to dangers in the process of manufacturing an aircraft.

## METHODOLOGY

The method used in this paper is a literature research. Various online library catalogues, such as the library of the Technical University of Darmstadt, Germany and the online library of the Faculty of Engineering of University of Porto have been searched for references and studies about this topic. Also, different journal databases with multiple different keywords, such as risk assessment, safety, transportation, aviation, aircraft, production and manufacture have been searched. Examples here are the websites of Scopus, Science Direct, Web of Knowledge, Google Scholar and Springer. For this research, the search ranged from articles to journals, books and conference papers. It was searched mostly for papers, published in the last four years (since 2015). If articles were found, which are important for the topic, these were also considered, even if they are older than four years. The languages searched in, were English and German. For the statistics from companies, such as Airbus, the data was taken directly from



their homepage.

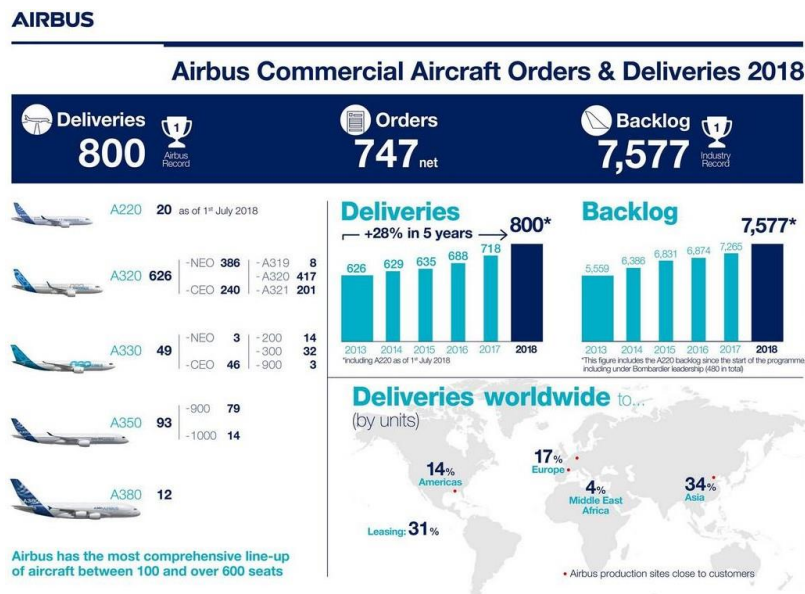


Figure 1. Airbus deliveries in the past five years (Airbus.com)

## RESULTS AND DISCUSSION

The production of an airplane dangles multiple dangers. It is important that every step is very well coordinated and planned. The production of an Airbus A320 takes about one year, over this cycle time, lots of risks and dangers occur (Airbus Press Office, 2019). If the risks are not treated correctly, the consequences are dangerous, not only for the workers and people that are involved in the production process, but also for the passengers that will fly with the airplane later on. Mechanical failures made whilst constructing and producing airplane parts lead to multiple crashes in the past. Examples here are the crash of a DC-10 at Chicago in 1979 happened due to engine failure, another DC-10 crashed in Paris in 1979 due to problems with the door system. Lots of people died because risks in the production process were overseen (Janic, 2000). Next to these later occurring risks, the workers in the manufacturing process face lots of dangers. One of these risks is the scale of the product. The size of the final product, an aircraft, means that the individual components that make up the product are also larger compared to other products (Bates, Sturges & Hutchinson, 1999). This implies, that workers have to work at greater heights to carry out their tasks. Many structures must be used to provide a safe and firm hold, both for the components and for the workers. Still, operatives are facing the danger of falling down or dropping tools on other people while working on these structures (Figure 2). A further factor in this area is that due to the shape of the aircraft much overhead work has to be carried out, sometimes at great heights. This work has been proven to be the most stressful for the human body, and these risks can lead to many physical problems with the body. One big risk factor in the aviation industry is the transportation of the parts. Most airplanes are produced at different locations. At the example of Airbus, they produce in various countries in Europe (Figure 3). Especially the transportation of the wings are often risky and dangerous due to the location of the factory in the United Kingdom (UK) (Mas Morate et al., 2013). The wings have to be maneuvered through small towns and roads, which are not constructed for carrying such a big transport, as seen in Figure 4.



Figure 2. Airbus Plant (Assembly Magazine)

Hazards occur for the traffic, the infrastructure, the workers and external people. Also, the traffic has to be prevented and shut down at some points because operating with the wings cannot continue without risks. Besides these problems, the transport of parts of the aircraft is carried out by Beluga airplanes, container ships and Roll-on/Roll-off vessels (Fig. 3). In addition to transport between the individual factories, there are also risks associated with transport within a site. Some of the parts are so large that big transport vehicles are needed, which are moved either by articulated lorry or by hand with remote control. Here, too, accidents can occur, some of which are particularly dangerous for the workers due to the size of the transports. Next to these risks, mostly according to the scale and complexity of the aircraft manufacture, lots of dangers occur, that are also known in other production lines. Starting with errors that occur during production planning. Processes that are dangerous from the outset due to organizational errors. These errors can appear in a wide range. Starting with the wrong composition of components, through the use of the wrong machines, to electrical faults that can lead to fires or short circuits, which in turn can be dangerous for the workers. The shaping of the material is dangerous, due to the high temperature, workers have to deal with. The assembly of the individual parts is dangerous as high forces are used, especially screws are exposed to high residual stresses. Many machines are used to support the workmen, they can fail or malfunction, which can be dangerous for the workers. The spraying of the parts at the end is poisonous, the operatives have to be careful that they wear the right protective clothing to avoid damage. Besides all these technical and mechanical risks and dangers, there is still the danger of human failure. This can be the result of many causes, for example, insufficient concentration, inability or fatigue due to shift work. However, these risks are difficult to assess as they depend on the human factor and are therefore different for each worker. The risks mentioned are only a few in the entire production process. Many other risks are not known or are classified as harmless.

**A320 Family workshare + transport**

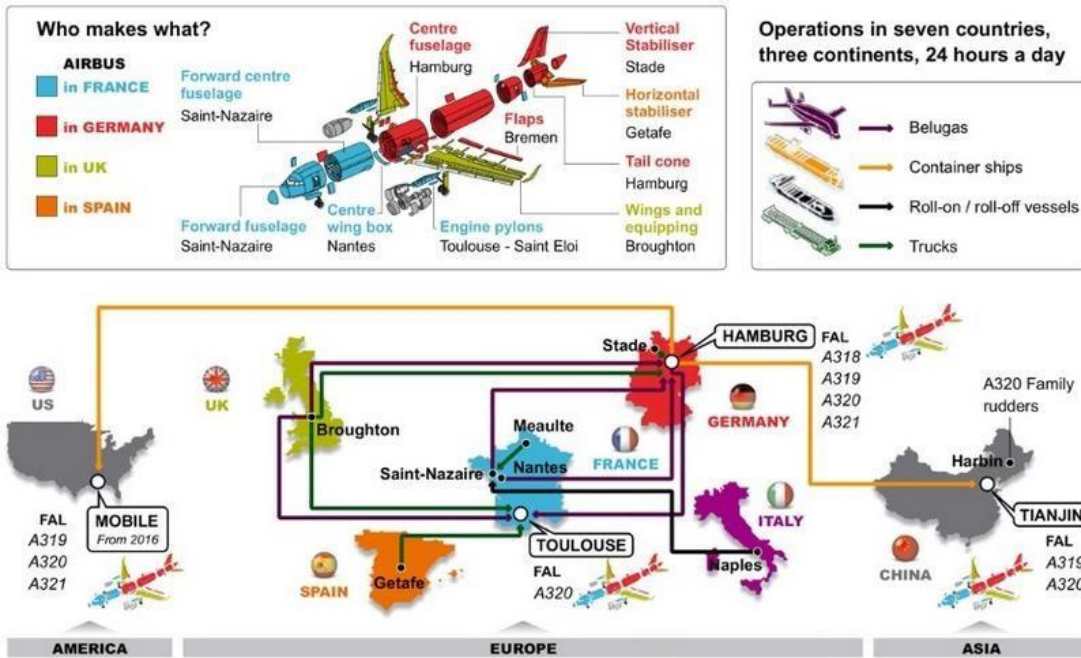


Figure 3. Production sites and transport vehicles of an A320 from Airbus (Modern Airlines)



Figure 4. Transport of an Airbus wing in the United Kingdom (Geograph.org)

**CONCLUSIONS**

There are many different risks involved in producing aircraft, many of which are known. However, there are always risks and dangers that are overlooked or classified as harmless. There are lots of different approaches to finding and classifying these risks. These approaches range from the classification of every single part of an aircraft, starting with the smallest screw, to assessment procedures involving component ubiquity and geopolitical instabilities (Bains et al., 2016). Other approaches also include enterprise resource planning. These methods help to identify and classify the risks and dangers in production, but risks remain, such as the transport

of parts (Sharma & Gupta, 2014). Hazards must continue to be expected here. It will never be possible to eliminate all risks during production. In order to find the best method to improve risk assessment, the safety studies must be intensified, new approaches must be developed, and the risk assessment process must be improved. This paper gives a first short overview of the difficulties in the manufacturing process of an aircraft. More studies need to be carried out to get a complete overview and proceed further.

## References

- Mas Morate, F., Menéndez Cuñado, J. L., Oliva Olvera, M., & Ríos Chueco, J. (2013). Collaborative Engineering: an Airbus case study. *Procedia Engineering*, 63(null), 336-345.
- Sharma, A., & Gupta, S. (2014, February). Identifying the role of ERP in enhancing operational efficiency and supply chain mobility in aircraft manufacturing industry. In *2014 International Conference on Issues and Challenges in Intelligent Computing Techniques (ICICT)* (pp. 330-333). IEEE.
- Bains, P., Ferris, K., Gregoire, J., Kim, J., Kozloski, J., Lazenby, J., ... & Fleming, C. (2016, April). Risk analysis of globalized airline supply chains. In *2016 IEEE Systems and Information Engineering Design Symposium (SIEDS)* (pp. 44-48). IEEE.
- Airbus Press Office (2019). A320 FAMILY: The most successful aircraft family.
- Bates, M. B., Sturges, J. L., & Hutchinson, B. (1999). Project Management Techniques and Procedures: A comparison of construction contracting and aircraft manufacture. In *Proceedings of the 2nd International Conference on Construction Industry Development, and 1st Conference of CIB TG* (Vol. 29).
- Plan, A. C. E. (2007). Federal Aviation Administration. *US Department of Transportation, Washington, DC, (May, 1983)*.
- Janic, M. (2000). An assessment of risk and safety in civil aviation. *Journal of Air Transport Management*, 6(1), 43-50.
- Altfeld, H. H. (2016). *Commercial aircraft projects: Managing the development of highly complex products*. Routledge.
- Turner, J. S. (n.d.). Moving an Airbus A380 wing #2 (C) John S Turner. Retrieved April 2, 2019, from <https://www.geograph.org.uk/photo/3829924>
- Doornbos, P. (2015). Airbus A320 - Assembly. Retrieved April 6, 2019, from <http://www.modernairliners.com/airbus-a320-introduction/airbus-a320-assembly/>
- Airbus achieves new commercial aircraft delivery record in 2018. (n.d.). Retrieved April 7, 2019, from <https://www.airbus.com/newsroom/press-releases/en/2019/01/airbus-achieves-new-commercial-aircraft-delivery-record-in-2018.html>
- Airbus Begins Construction of \$300 Million Assembly Plant in Alabama. (2019, February 12). Retrieved April 7, 2019, from <https://www.assemblymag.com/articles/94754-airbus-begins-construction-of-300-million-assembly-plant-in-alabama>

## Hand tools characteristics in slave labour

Gairo Garreto<sup>1</sup>, J. Santos Baptista<sup>2</sup>, Antônia Mota<sup>3</sup>, António Torres Marques<sup>4</sup>

<sup>1</sup>Federal Institute of Education, Science and technology of Maranhão, BR ([gairo@ifma.edu.br](mailto:gairo@ifma.edu.br)), <sup>2</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([jsbap@fe.up.pt](mailto:jsbap@fe.up.pt)) ORCID 0000-0002-8524-5503, <sup>3</sup>Federal University of Maranhão, BR ([motaufma@gmail.com](mailto:motaufma@gmail.com)), <sup>4</sup>Faculty of Engineering, University of Porto, PT ([marques@fe.up.pt](mailto:marques@fe.up.pt)) ORCID: 0000-0001-9388-2724  
[https://doi.org/10.24840/978-972-752-260-6\\_0073-0077](https://doi.org/10.24840/978-972-752-260-6_0073-0077)

### Abstract

**Introduction:** The Brazilian economy was based on slave labour, particularly in rural areas, until the end of the nineteenth century. Traditionally, the developed studies regarding this period present a historical or sociological perspective on this subject. **OBJECTIVE:** Based on analyses of historical descriptive studies, this work aimed to make an objective investigation of the slaves' safety conditions, concerning the use of equipment and tools, and accidents with an injury resulting from such use. **Methodology:** The selected databases to conduct the research were: Science Direct, Scopus, Web of Science, Criminal Justice, EBSCO, Business Source Complete, as well as original historical documents. Regarding the selection process, descriptive studies involving the rural work of the slaves in colonial and imperial Brazil were considered without language restrictions. The tools' safety conditions, as well as the work performed by them, were evaluated. **Results:** The searches in the six databases provided, initially, 36,355 references. After applying the exclusion criteria, 9 were selected to full-text reading. By applying the snowballing technique, 19 more papers were added, resulting in a total of 28 works. Once applied the eligibility criteria, 20 papers were included in the systematic review: 8 papers, 3 books, and 9 rare books. The tools used by the slaves ranged from simple wooden rods to cutting hand tools such as hoes, axes, and scythes, made of metal alloys. All of them had great relevance, and their use was widespread in rural properties. Compared with the hand tools used in the twenty-first century, those considered ideal in the nineteenth century tended to have greater mass and larger wooden cables. The shapes and dimensions of the metal tools did not change significantly in this period. **Conclusions:** The assessed studies indicated the existence of similar tools in all Brazilian regions, which suggest that accidents with injuries occurred similarly among slaves. Regarding energy expenditure, these values are smaller with the tools of the XXI Century, due to the decrease of the mass and the length of the cable (smaller momentum values - Nm).

**Keywords:** Slavery, Modern slavery, Hand Tools, Injuries, Review.

### INTRODUCTION

In the historical period when slavery was legal in Brazil, these workers were the primary labour source (Albuquerque, 2006), performing most of their tasks with only hand-tools due to embryonic development of mechanisation at the time. Activities such as deforestation, digging, planting, weeding and harvesting, and even the engraving, was often moved by the use of human force or pack animals (Taunay, 1839). As slaves were considered a patrimonial asset, the invested capital should be amortised and generate profit in order to guarantee the economic return to the owner (Pinsky, 1988). This implied a return on invested capital in the acquisition of slaves in just a few years. In order to do so, the slaves worked an unreasonable number of hours, in precarious conditions of safety and hygiene, with inadequate food in both quantity and quality. On top of these conditions, were added the beatings and inadequate health care. It was necessary to obtain, with minimum costs, the highest profitability possible. Under these conditions, the health and the safety of these populations were very precarious. Nowadays, neo-slavery or modern slavery causes incalculable damages not only to people in these conditions but also to society, the economy and the environment. Under these conditions, workers are exposed to the inherent risks of each activity, but it is also likely that those risks will be worsened by the precarious conditions in which the work is done and also by the long hours during which it takes place. Occupational diseases and accidents occur without any control, in particular, because of the clandestine nature of this kind of work. According to international treaties, agreements, declarations, and conventions, slave labour is characterised as a severe form of human rights violation (Ramos Filho, 2008). However, the International Labour Organization (ILO) estimates that more than 40 million people are subject to slave labour worldwide (OIT, 2017). In some countries, such as Brazil, slavery is rejected even in the constitution; in other

countries, the same rejection is stated at different legislation levels. According to the Brazilian Law, there are four aggravating factors, which isolated or combined can characterise a condition analogous to slavery: (i) forced labour by third parties; (ii) subjection, by third parties, to exhaustive working hours; (iii) subjection, by third parties, to degrading working conditions; (iv) travel restriction, by any means, based on debt contracted with the employer or his representative. However, these four legal characteristics, namely degrading working conditions and exhaustive working hours, are also related to OSH conditions. So, these general minimum conditions of working conditions are also described in the Brazilian Safety and Health Regulatory Standards. Consequently, from this double characterisation, these working conditions tend to be regarded as mere standards violations, and therefore, no longer considered as a crime. This analysis bias allows this situation to be punishable only with a fine. Thus, in many situations of modern slavery, the Penal Code framework ends up not being applied and, in its place, only the general labour legislation is. With this interpretation of the legal framework, neo-slave labour's users escape from the punishments of their crimes (Ramos Filho 2008). With this work, it is expected to help to raise evidence and methodologies for the approach and identification of the new forms of slavery in the different parts of the world where these practices are still a reality.

## METHODOLOGY

This study began as a thematic review where descriptive studies covering the rural working conditions of slaves in colonial and imperial Brazil were selected. In this first phase, where the selection of the most recent historiographical research was made, the following databases were searched: Science Direct, Scopus, Web of Science, Criminal Justice, EBSCO, Business Source Complete, within the time frame following 2014. In all of them, the same combination of keywords was used: slavery and work. No language restrictions were imposed, and duplicate references were excluded. In the second phase, the potentially relevant articles were selected based on the analysis of titles and abstracts. Research papers without references to official or environmental descriptions of slave labour activities were also excluded. As inclusion criteria were established: (i) the existence of direct descriptions of the themes related to the study, (ii) dealing with Brazilian slavery of the nineteenth century and (iii) being recognised as a reliable source. Thus, there were only included works that, after analysing the full-texts, allowed the extraction of relevant information using, for that, a standardised form (complete references, country region, used tools and accidents with injuries). After completing the second phase, all bibliographic references of all the selected articles were analysed (without distinction on the publication type), which allowed the analysis of thesis, dissertations, books and rare books (original publications dating from the eighteenth and nineteenth centuries). It is important to note that the primary sources (rare books) were the richest in detailed descriptions of sought requirements. In the last phase, the data on the tools used by the captive workers, and the accidents with injuries caused by these same tools were collected. In this phase, conversions of measure units related to the tools were carried out. Later, the historical data found were compared with data from free poor workers of the same period, to highlight only the usual exposure situations related to captive workers.

## RESULTS

After the research, 36,355 records were identified, from which, 9 were selected for full-text screening after applying the exclusion criteria. Due to date, 28,498 records were excluded, and 4,312 were withdrawn after the publication requirement in journals was applied. Finally, 3,444 records were excluded because they were out of scope, and 92 after reading its abstracts, which

did not indicate a possible positive result for the presence of relevant reports to the research. To the 9 articles included, another 19 papers cited in their references or obtained from other sources were added, in a total of 28 papers selected for full-text reading. After analysing these articles, 8 were excluded because they did not meet the defined inclusion criteria. In the end, 20 papers were included in the review: 8 articles, 3 books, and 9 rare books. From the 20 papers, Albuquerque (2006) refers to the problem of crushing hands and arms in sugarcane mills; Assunção (2015) analyses how axes and pylons cause mutilations in work accidents; de Carvalho Cabral (2015), describes tools such as hoes, axes, and scythes; de Lima (2015) underlines that 46.4% of slaves have work-related injuries; Debret (1835) presents the axe as the cause of punishment injuries; do Alferes & Werneck (1878) refers the risk of crushing accidents with hoes, axes and scythes; Rugendas (1834) describes in detail the type of axe used; Eugenio (2015) refers to the mining pick, as well as the injuries and deaths by burial in excavation; Imbert (1839) describes hand-tool injuries, namely by knife and sickle; Lima, de Oliveira, & dos Santos (2016) reinforce the analysis that 46.4% of slaves present traumatic injuries related to work; Magalhães (1858) describes the wooden stick used for navigation; Marques (1870) describes hoes, axes, scythes, and saws; Pinsky (1988) describes the role of the hoe and pestle in the deaths by the employee's violence and injuries due to occupational accidents; K. Rodrigues (2009) develops a study in which it is demonstrated that more than 40% of the illnesses are caused by traumatic injuries and many deaths are caused by mistreatment; K. Rodrigues (2010) describes the hoes, axes, and sickles used by the slaves; Schwartz (1988) presents the hoes, axes, scythes, and picks as being in the origin of accidents and mutilations in mills and accidents due to extreme fatigue; Spix (1824) describes hoes, scythes, knives, and axes; Taunay (1839) describe shovels, plows and axes; Vieira Junior & Martins (2015) describes the scythe and the axe in their most common version; and finally, Viveiros (1954) also presents a detailed description of axes, scythes, shovels, and spades.

## DISCUSSION

The usage of hand-tools (hoes, axes, and scythes) by slaves was the usual source of mechanical hazards and resulted in a large number of injuries. The tools used by the slaves could be elementary like the wooden rod, quite diffused in the fluvial navigation in substitution of the oar (Magalhães, 1858). Manual cutting tools such as hoes, axes, and scythes had great relevance and their extensive use in rural properties was described by several authors (de Carvalho Cabral, 2015; Pinsky, 1988; Schwartz, 1988; Vieira Junior & Martins, 2015). The fundamental importance of these tools to the productivity and profitability of a farm was not always understood by the farmers, who sometimes acquired inadequate tools for the service or did not give proper attention to its maintenance and edging (do Alferes & Werneck, 1878). However, the concern for acquiring better and modern tools was widespread among farmers. As an example of concern with the modernisation of tools as a way of increasing productivity, the introduction, in the first half of the nineteenth century, of the American woodcutter axe, which was wider and thinner than the Portuguese axe can be pointed out (Taunay, 1839). In addition to the better productivity, this innovative axe cost about three times more than the Portuguese technology used until then (Viveiros, 1954), which did not avoid its consolidation as the most sought type of axe by the farmers of the time. Compared to the used hand-tools in the twenty-first century, those considered ideal in the nineteenth century (do Alferes & Werneck, 1878) tended to have higher mass and longer wooden cables (Table 1), but the shapes and dimensions of the tools' metallic structures did not change significantly during the same period of time. Regarding energy expenditure, these values are smaller with the tools of the XXI Century, due to the decrease of

the mass and the length of the cable (smaller moment values - Nm). In Table 1, for the moment (Nm) calculation, the wood stick and the points of an effective handle on the cable by the workers were disregarded. The calculation of the moment (Nm) has the sole purpose of demonstrating the existence of a significant difference in a physical effort by tool stroke when comparing the two historical periods. The decrease in the mass of the tools was mainly due to the evolution of the mechanical processes used in manufacturing. With a particular focus in stamping and cold forging occurring below the recrystallisation temperature of the metal, providing higher resistance to the parts, due to the hardening in the material during its conformation (Helman & Cetlin, 1993; Rodrigues & Martins, 2005).

**Table 1.** Comparison of hand-tools - Measures of mass, cable size, and momentum (Nm).

Tool	19th-century common tool <sup>1</sup>			21st-century common tool <sup>2</sup>		
	Mass (kg)	Grip (m)	P (Nm)	Mass (kg)	Grip (m)	P (Nm)
Long hoe	Approx. 1.80	1.43	25.24	0.80 to 1.25	1.30 to 1.45	10.20 – 17.77
Woodcutter ax *	1.35 to 2.25	1.10	14.56 – 24.27	1.50 to 2.00	0.90	13.24 – 17.65
Big sickle	0.80 to 1.60	1.32	10.36 – 20.71	0.57 to 0.8	1.10	6.15 – 8.63

<sup>1</sup> (do Alferes & Werneck, 1878; Taunay, 1839)

<sup>2</sup> (Tramontina, 2018)

\* American woodcutter axe

## CONCLUSIONS

The analysed working conditions, as well as the tools used in slave labour, and the traumatic injuries from it, are similar in all regions of Brazil, despite the continental dimensions of the country, the climatic differences and the adopted agricultural practices. When comparing the tools of the nineteenth century with those of the twenty-first century, it can be observed a significant decrease in size and mass, which led to a decrease in a physical effort by tool-stroke for twenty-first-century workers. However, the changes within the use of better equipment in slave labour are mainly the ability to produce more and generate more significant capital gains. The Brazilian Farmer's Handbook (Taunay, 1839) explains that only the activities performed with the "use of all the forces of the body" were regarded as work. No matter the type of tool, enslaved workers' power is always extracted to the maximum since this is only considered as one of the production factors.

## Acknowledgments

The authors would like to thank the support of *Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Maranhão (FAPEMA) / Secretaria de Estado da Ciência, Tecnologia e Inovação (SECTI)* and *Governo do Estado do Maranhão* for funding this research.

## References

- Albuquerque, W. R. d. (2006). *Uma história do negro no Brasil*. Brasília: Fundação Cultural Palmares. ISBN: 85-88070-022.
- Assunção, M. R. (2015). *De caboclos a bem-ti-vis: formação do campesinato numa sociedade escravagista: Maranhão, 1800 - 1850*. São Paulo: ANNABLUME.
- de Carvalho Cabral, D. (2015). Into the bowels of tropical earth: leaf-cutting ants and the colonial making of agrarian Brazil. *Journal of Historical Geography*, 50, 92-105. doi:<http://doi.org/10.1016/j.jhg.2015.06.014>
- de Lima, P. V. S. F., de Oliveira, K. A., & dos Santos, D. L. R. (2016). Aspectos gerais da saúde dos escravos no Brasil: revisão de literatura. *Gestão e Saúde*, 7(1), Pág. 471-489.



Debret, J. B. (1835). *Voyage pittoresque et historique au Brésil*. Paris: Firmin Didot Frères. From The New York Public Library. URL: <https://digitalcollections.nypl.org/items/510d47df-7993-a3d9-e040-e00a18064a99> and URL: <https://digitalcollections.nypl.org/items/510d47df-7988-a3d9-e040-e00a18064a99>

do Alferes, P., & Werneck, F. P. L. (1878). *Memoria sobre a fundacao e costeio de uma fazenda na provincia do rio de janeiro*.

Eugenio, A. (2015). Luis Gomes Ferreira reports on the health of slaves in his work entitled *Erário mineral (1735)*. *Historia, Ciencias, Saude - Manguinhos*, 22(3), 881-897. doi:10.1590/S0104-59702015000300013

Helman, H., & Cetlin, P. R. . (1993). *Fundamentos da conformação mecânica dos metais*. Brazil: Universidade Federal de Minas Gerais, Escola de Engenharia, Fundação Christiano Ottoni.

Imbert, J.-B. A. (1839). *Manual do fazendeiro, ou tratado doméstico sobre as enfermidades dos negros (2nd ed.)*. Rio de Janeiro: Typographia Nacional. <https://archive.org/details/DELTA539211FA>

Lima, C. A. M. (2015). *Frontier, sugarcane and trafficking: Slavery, disease and death in capivari, são paulo, 1821-1869*. *Historia, Ciencias, Saude - Manguinhos*, 22(3), 899-919. doi:10.1590/S0104-59702015000300014.

Magalhães, D. J. G. d. (1858). *A Revolução da Provincia do Maranhão: 1839 - 1840*. São Luís: Typographia Progresso. URL: <https://digital.bbm.usp.br/handle/bbm/4156>

Marques, C. A. (1870). *Diccionario histórico-geográfico da provincia do Maranhão*. Maranhão: Typ. do Frias.

OIT, O. I. d. T.-. (2017). *Trabalho Forçado no Brasil*. Retrieved from <http://www.ilo.org/brasil/temas/trabalho-escravo/lang-pt/index.htm>

Pinsky, J. (1988). *Escravidão no Brasil (7 ed.)*. São Paulo: Contexto. ISBN: 978-8506071571

Ramos Filho, W. (2008). *Trabalho degradante e jornadas exaustivas: crime e castigo nas relações de trabalho neo-escravistas*. *Revista Direitos Fundamentais & Democracia*, 4(4). URL: <http://revistaeletronicardfd.unibrazil.com.br/index.php/rdfd/article/view/213>

Rodrigues, J., & Martins, P. (2005). *Tecnologia mecânica: Tecnologia da deformação plástica*.

## Thematic review on the slaves' feeding in colonial and imperial Brazil

Gairo Garreto<sup>1</sup>, J. Santos Baptista<sup>2</sup>, Antônia Mota<sup>3</sup>, Mário Vaz<sup>4</sup>

<sup>1</sup> Federal Institute of Education, Science and technology of Maranhão, BR ([gairo@ifma.edu.br](mailto:gairo@ifma.edu.br)), <sup>2</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([jsbap@fe.up.pt](mailto:jsbap@fe.up.pt)) ORCID 0000-0002-8524-5503, <sup>3</sup> Federal University of Maranhão, BR ([motaufma@gmail.com](mailto:motaufma@gmail.com)), <sup>4</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([gmavaz@fe.up.pt](mailto:gmavaz@fe.up.pt)) ORCID 0000-0002-6347-9608  
[https://doi.org/10.24840/978-972-752-260-6\\_0078-0081](https://doi.org/10.24840/978-972-752-260-6_0078-0081)

### Abstract

**Introduction:** Until the end of the nineteenth century, the Brazilian economy was based on slave work. In a historical period of incipient mechanization, the main sources of energy used from the transportation to the activation of the available rudimentary equipment, were of animal origin, among them the Man. The enslaved workers spent their energy performing tasks using, in most cases, only hand tools, such as axes, scythes and hoes. Human strength was the only source of available energy for the more elaborated activities that could not be done by animals. These activities ranged from deforestation to digging, from planting to weeding or harvesting. This research aimed to obtain a detailed and descriptive framework of energy replacement conditions of slave labour, through a review of historical sources and contemporary studies. **Methodology:** Six databases were searched with timeframe after 2014, as well as original historical documents. A snowballing approach allowed finding references before 2014. The studies were selected without language restrictions. The quantification of energy recovery was done based on quantity, quality and type of served food; the energy value of those foods; and the average of slaves' energy expenditure in rural activities. **Results:** The searches in the six databases provided initially 36,355 articles. After screening and analysing all this information, 16 were included: 6 articles, 5 books and 5 rare books. **DISCUSSION:** The selected studies classified slaves' feeding as insufficient to energy replacement, of low quality and classified as bulk feed by the researchers, that is, it consisted of low-quality foods and its preparation was carried out carelessly as regards hygiene, ways of cooking or seasoning. This diet was repeated daily, leading to the occurrence of digestive system diseases. The difference between the average daily energy expenditure and the replacement of this energy using the supply provided by the slave owners, was also significant. The reduction of this difference was fundamental to human labour and was supplied in different ways. A rather usual one was an increase in the regular supply of alcoholic beverages. **conclusions:** The analysed studies suggest the existence of precarious and similar energy replacement conditions, among the slaves in the different regions of Brazil.

**Keywords:** Slavery, Modern slavery, Caloric supply, Caloric expenditure, Occupational safety and health, Review.

### INTRODUCTION

The slavery in Brazil remained legalised until 1888 (Lei Aurea" - 13th May 1888). Until then, the slaves were the primary labour force, working in the fields which products were mainly aimed at exportation, such as coffee, sugar and cotton production (Albuquerque, 2006). Life expectancy of the slaves at birth was 30% lower than that between the free population (Schwartz, 1988) and the mortality rate, due to the hard working conditions, caused a decrease among slaves population about 4,5% per year, only restored by the importation of new slaves from Africa (Viveiros, 1954). Slave labour, or in similar conditions, continues to be a reality all around the world. However, according to international treaties, agreements, declarations and conventions for the protection of human rights, the precarious conditions in which slave labour develops characterise it as a severe form of violation of these rights (Ramos Filho, 2008). The number of people subject to slavery is estimated at 27 million, being the highest concentration in the Southern Hemisphere (PioVesan, 2006). This work is justified as a first step to study and understand the feeding conditions of Brazilian slave labourers, at a time when slavery was legal, but in a current OSH perspective. It is hoped, with this work, to contribute to raising clues and methodologies to approach and identify this type of situations in the different places of the world where these practices are still a reality.

## METHODOLOGY

A review was done in the initial phase of this research. Studies on the conditions of agricultural work of the slaves in Brazil from the 18th and 19th centuries were selected. In a first step were selected recent studies addressing directly or indirectly this subject, through the research in the following databases: Science Direct, Scopus, Web of Science, Criminal Justice, Ebsco, Business Source Complete with publication in 2014 or later. In all databases, the same combination of keywords was used: slavery and work. No language restrictions were imposed, and the duplicate references were deleted. In the second step, potentially relevant articles were selected based on titles and abstracts. The complete texts of the selected articles were read in full. The information was extracted by completing a standard form with data pertinent to the study (reference, region of the country, description of the agricultural activity, working day and composition of the supply of beverages quantity and quality of food). The bibliographic references of all the selected articles were then analysed for other works, without distinction of type, date or place of publication. This approach allowed us to consider theses, dissertations, rare books and books (publications dating from the eighteenth and nineteenth centuries). The primary sources and the rare books were the most relevant sources due to their detailed descriptions. In the third and last stage, elements related to the general conditions of energy replacement were collected: quantity and quality of food supplied, the composition of these foods and supply of alcoholic products. Finally, the amount of energy supplied, based on the meals provided to the slaves, was compared with the daily caloric expenditure, calculated according to the reports of the developed activities. The daily energy expenditure was measured based on the standard routine, determined according to the descriptions of the consulted authors. The calculations were done using two recognised methodologies: the table of Classification of metabolic rate levels of ISO 7243/2017 (ISO, 2017) and the Occupational Hygiene Standard (OHS 06) of the Jorge Duprat and Figueiredo Foundation (FUNDACENTRO, 2002).

## RESULTS

The searches in the six databases provided 36,355 articles. The temporal delimitation eliminated 28,498 articles. Another 4,312 were withdrawn because they were not published in peer-reviewed journals, and 3,536 were excluded because they were off topic. Based on the references of the nine remaining articles, more 19 papers were pre-selected. After analysing the full text of these 28 (19 + 4) records, 16 articles were selected: 6 articles, 5 books. References to the inadequacy and poor quality of food available to enslaved workers are recurrent. The composition of this diet is also described as insufficient, with a predominance of cassava flour, maize and beans. Animal proteins were rare. Alcoholic beverages were provided on a daily basis to supplement the calorie replacement or as a stimulant.

## DISCUSSION

### Caloric Supply

Although they were the driving force behind the plantations and represented the most significant resources of rural properties, slaves were poorly fed. The studies refer to the feeding of slaves as insufficient for the necessary energy replacement. In addition, it consisted of bad

quality food and its confection was carelessly carried out in relation to hygiene, cooking or seasoning. To make matters worse, the daily diet was almost always the same, which led to the occurrence of diseases in the digestive system (Eugenio, 2015). It was considered as ideal the diet prescribed to the slaves of Public Finance by the Decision nº 151 of August 25, 1829 (Chaia & Lisanti, 1974). By this rule, a daily portion of 344 g of dried beef (1077 kcal) or 459 g of fresh meat (987 kcal) should be available daily to the Treasury slaves; 29g of salt pork meat (202kcal); 83g of beans (269 kcal); 255 g of cassava flour (930,75 kcal). The diet should offer a total energy replacement of 2479 kcal. The underfeeding of slave population as a common practice among landowners was accompanied by the regular supply of alcoholic beverages as a form of caloric supplementation (Guzman, 2013). This practice was so widespread that, at the beginning of the nineteenth century, the rate of alcohol dependents among the slave population was estimated at 6.75% (Lima, Oliveira and Santos 2016).

#### Caloric Expenditure

In order to calculate the energy consumption, the daily routine of the slaves was divided by the main developed activities: (a) 12 hours of work with high metabolic rate, in the plantations; (b) 1 hour of low metabolic rate activities during meals; (c) 1 hour of moderate metabolic rate activities in the field trips; (d) 3 hours of moderate metabolic rate activities, developed at night; (e) 7 hours of rest or sleep. The total energy expenditure corresponding to the activities described (a, b, c, d, e) corresponds to 5935.5 kcal per day, adopting the methodology of ISO 7243: 2017 (ISO, 2017). This sum results in 6625 kcal per day if the calculation is performed by the Occupational Hygiene Standard - NHO 06, whose methodology was developed in Brazil by FUNDACENTRO. Accordingly, there is a significant difference between the average daily energy consumption by the slave and the replacement of that energy by its owners. However, the reduction of this difference was fundamental so that the work could be carried out, and was done in different ways. The most usual was an increase in the regular supply of alcoholic beverages (Pinsky, 1988).

#### **CONCLUSIONS**

In the nineteenth century, the general conditions of slave feeding in Brazil showed a significant difference between the energy consumed in the required daily activities and what was offered for its replacement. The two diets considered ideal by the slave owners were analysed, and their energetic values calculated. However, comparing the energy supplied with the estimated energy expenditure in the daily routine of a farm slave, these diets presented a very significant difference. In order to guarantee the necessary energy, a supplement was provided consisting of alcoholic beverages, sugar derivatives and pig fat. However, even with the supply of these high energy products, it was imperative that the diet is supplemented with the foods they could produce in the individual plantations they were forced to keep in the few moments allowed by the work routine. The general energy recovery conditions analysed were similar regarding the composition and quality of the offered diets and the energy expenditure in the planting activities throughout Brazil.

## Acknowledgements

The authors would like to thank the support of *Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Maranhão (FAPEMA) / Secretaria de Estado da Ciência, Tecnologia e Inovação (SECTI)* and *Governo do Estado do Maranhão* for funding this research.

## References

- Albuquerque, W. R. d. (2006). Uma história do negro no Brasil. Brasília: Fundação Cultural Palmares. ISBN: 85-88070-022.
- Chaia, J., & Lisanti, L. (1974). O escravo na legislação brasileira (1808-1889). *Revista de História*. ano XXV, 49(99), 241-248. DOI: 10.11606/issn.2316-9141.rh.1974.132589.
- Lima, P. V. S. F., de Oliveira, K. A., & dos Santos, D. L. R. (2016). Aspectos gerais da saúde dos escravos no Brasil: revisão de literatura. *Gestão e Saúde*, 7(1), pp. 471-489. DOI: 10.18673/gs.v7i1.22093
- Eugenio, A. (2015). Luis Gomes Ferreira reports on the health of slaves in his work entitled Erário mineral (1735). *Historia, Ciencias, Saude - Manguinhos*, 22(3), 881-897. doi:10.1590/S0104-59702015000300013
- FUNDACENTRO, F. J. D. F.-. (2002). Taxa Metabólica Por Tipo de Atividade. In. Brasília: Ministério do Trabalho. URL: <http://www.fundacentro.gov.br/biblioteca/normas-de-higiene-ocupacional/publicacao/detalhe/2013/3/nho-06-avaliacao-da-exposicao-ocupacional-ao-calor>
- Guzmán, R. A. F. (2013). The feeding of slave population in the United States, the caribbean, and Brazil: Some remarks in the state of the art. *América Latina en la Historia Económica*, 20(2), 5-35. DOI: [10.18232/alhe.v20i2.537](https://doi.org/10.18232/alhe.v20i2.537).
- ISO, I. O. f. S.-. (2017). Classificação dos níveis de taxa metabólica (ISO 7243/2017). In. Genebra: ISO.
- NEPA, N. d. E. e. P. e. A. (2006). Tabela Brasileira de Composição de Alimentos – TACO. In (2nd ed.). Campinas - SP: Unicamp. URL: <http://www.nepa.unicamp.br/taco/tabela.php?ativo=tabela>.
- Pinsky, J. (1988). *Escravidão no Brasil* (7 ed.). São Paulo: Contexto. ISBN: 978-8506071571
- PioVesan, F. (2006). Trabalho escravo e degradante como forma de violação aos direitos humanos. In: Velloso, Gabriel; Fava, Marcos Neves [Coord.]. *Trabalho escravo contemporâneo: o desafio de superar a negação*. São Paulo: LTr, 151-165. ISBN: 8536108754
- Ramos Filho, W. (2008). Trabalho degradante e jornadas exaustivas: crime e castigo nas relações de trabalho neo-escravistas. *Revista Direitos Fundamentais & Democracia*, 4(4). URL: <http://revistaeletronicardfd.unibrazil.com.br/index.php/rdfd/article/view/213>
- Schwartz, S. B. (1988). *Segredos Internos: Engenhos e escravos na sociedade colonial 1550-1835* (L. T. Motta, Trans.). São Paulo: Companhia das Letras. ISBN:9788571640122.
- Viveiros, J. d. (1954). *História do Comércio do Maranhão, 1612 - 1895*. São Luís: Associação Comercial do Maranhão. URL: <http://memoria.org.br/pub/meb000000461/histcomvol2mar/histcomvol2mar.pdf>

# Predicting thermal sensation through local body skin temperatures to assess thermal comfort: a short systematic review

R. P. Martins<sup>1</sup>, Daniele Costa<sup>2</sup>, J. C. Guedes<sup>3</sup>

<sup>1</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (rpmar@fe.up.pt) ORCID 0000-0001-8438-0597, <sup>2</sup>Faculty of Engineering, University of Porto, PT (daniele.costa@fe.up.pt), <sup>3</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (jccg@fe.up.pt) ORCID 0000-0003-2367-2187  
[https://doi.org/10.24840/978-972-752-260-6\\_0082-0087](https://doi.org/10.24840/978-972-752-260-6_0082-0087)

## Abstract

**Introduction:** The skin plays a substantive role in the thermoregulatory process. The maintenance of a constant internal body temperature by the thermoregulatory system, partially achieved by vasoconstriction and vasodilation, makes the skin temperature an important mechanism to indicate the thermal state of the comfort of a given subject. However, this parameter is still little considered in studies that evaluate thermal comfort. Therefore, this work aims to investigate the use of skin temperatures as a predictor of thermal sensation to assess thermal comfort. **Methodology:** A short systematic review based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was performed to assess scientific publications that evaluated thermal comfort considering the skin temperature as a predictor. The review search strategy considered the use of "thermal comfort" and "skin temperature" as keywords in the 'Web of Science', 'Scopus', 'PubMed', and 'Academic Search Ultimate', 'Taylor and Francis' and 'Sage Journals' databases. Eligibility criteria considered articles that conducted experiments under steady-state environmental conditions and that considered skin temperature measurements in the assessment of thermal comfort. **Results and Discussion:** The search resulted in the identification of 73 articles, from which five were considered suitable for the systematic review. Skin temperatures were measured at a variety of measurement points throughout the reviewed articles. Overall, the mean skin temperature of female subjects was lower than the mean skin temperature of male subjects at each experimental temperature, at the same level of thermal comfort. Forehead, chest and abdomen were evidenced as the best measuring points and presented the highest correlation between thermal sensation and skin temperature. **Conclusion:** The systematic review has shown that the comparison between the selected articles is hampered by the lack of uniformity in the adopted experimental procedures. There seems to be a relationship between thermal sensation and skin temperature responses. Future studies should consider more uniform experimental procedures. Besides, there is the need of increasing the size of the experimental sample and to consider different target groups (such as children or the elderly) to verify if the prediction of thermal comfort based on skin temperature exhibits the same trends when compared to healthy adults.

**Keywords:** Skin temperature, Thermal comfort, Thermal sensation vote, Systematic review.

## INTRODUCTION

Humans are highly sensitive to thermal conditions, which affects the physiological state, the mood, and behaviour of individuals (Parsons, 2003). The maintenance of constant internal body temperature by the thermoregulatory system is partly achieved through the mechanism of vasoconstriction and vasodilation (De Dear, Ring & Fanger, 1993). These processes may decrease or increase skin blood flow to prevent heat loss or to dissipate heat, respectively, protecting the body against heat stress or hypothermia (Charkoudian, 2003), resulting in decreased or increased body temperature. Due to these mechanisms, the skin temperature acts as a parameter to indicate the thermal state of the comfort of a given subject. Thermal comfort is defined by ASHRAE (2010) as the "condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation". Such assessment of thermal comfort often considers a thermal index to describe, design and assess thermal environments as experienced by individuals. In this context, skin temperature measurements are a relevant physiological parameter to be considered in the assessment of thermal comfort. However, the relationship between skin temperature and thermal comfort is still poorly evaluated in the scientific literature. Considering these aspects, the scope of this short systematic review is to investigate the use of skin temperatures as a thermal sensation predictor to assess thermal comfort.

## METHODOLOGY

This short systematic review considered the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, or simply PRISMA Statement, to conduct the review (Moher et al., 2009b). "Thermal comfort" and "skin temperature" were the defined search keywords. The search was conducted in the title search field of the search mechanism in the following databases: Web of Science, Scopus, PubMed, Academic Search Ultimate, Taylor and Francis, and Sage Journals. Once the search was completed, resulting in a total of 73 publications, which were exported from the databases and inserted into a bibliographic management software for screening. At first, all duplicate records were eliminated (40 publications). Then, the title and abstracts were examined, taking into consideration the inclusion criteria. The search considered only peer-reviewed scientific publications and articles published until April of 2019. A limitation of years of publication was not included to allow a more extensive identification of the existing scientific publications. All grey literature identified (conference articles, editorials, among others) was excluded since their quality is not certified by an expert peer-review process. Only articles written in English were included. Later, articles fulfilling the scope of the study were retrieved and assessed (19 articles). To be considered eligible, experiments should only be performed under steady-state environmental conditions (studies conducted in transient and non-uniform environmental conditions were not included). Only studies correlating skin temperature and the assessment of thermal comfort through thermal sensation were considered. The inclusion criteria only considered studies with human subjects but did not focus on a specific population of participants, disregarding their age group. A total of five articles were considered eligible and were discussed in the qualitative synthesis. The selection details of all relevant articles are shown in Figure 1.

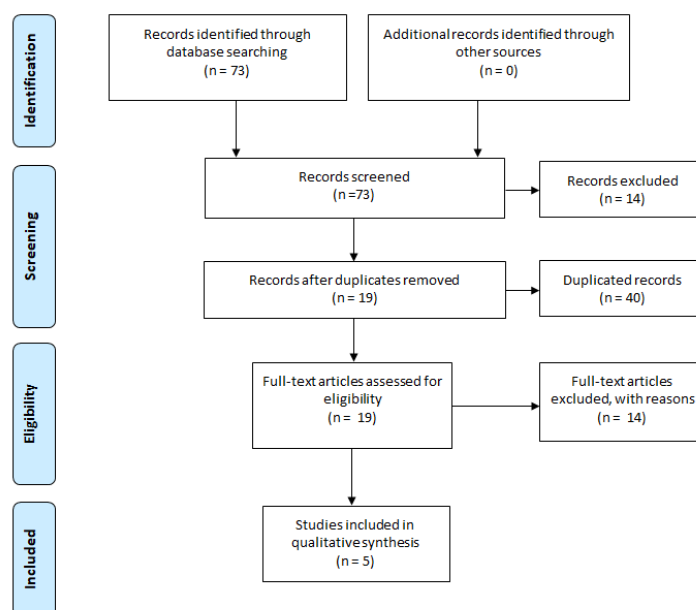


Figure 1. PRISMA Flowchart Diagram. Source: authors based on Moher et al. (2009)

## RESULTS AND DISCUSSION

This systematic review identified five articles with the scope of this study. The selected articles were published from 2007 to 2018. Regarding the geographical location, four articles were from China (Yao et al., 2007; Liu et al., 2011; Liu et al., 2015; Fang et al., 2018), and one from Poland (Bogdan, 2011). All articles conducted experiments in healthy adult humans.

### Sample characteristics

The characteristics of the sample population are presented in Table 1. Except for Bogdan (2011), all articles considered both male and female in the experiments. All the assessed articles considered a relatively young population (minimum of 20.5 and a maximum of 28.3 years), with a weight range between 47.0 to 83.1 kg. The number of participants is relatively small in all articles, which is reflected in a reduced confidence interval in their findings. All adopted protocols were approved by an ethics committee. Information on the given consent of participants to participate in the experiments is reported in all of the reviewed articles, except for Bogdan (2011).

**Table 1.** Summary of participants' characteristics

Reference	Sample	Age (years)	Height (cm)	Weight (kg)
Bogdan, 2011	14 M	22±1.5	181±35	75.6 ±7.5
Fang et al., 2018	8M, 8F	23.81±1.27	167±7	57.25±7.99
Liu et al., 2015	12 M, 10 F	23.9±0.4	170±1	61.2±1.6
Liu et al., 2011	12 M, 10 F	23.9±0.4	170±1	61.2±1.6
Yao et al., 2007	10 M, 10 F	25.3±3.0	M:172±4/F:161±5	M:63.6±6.2/F:52.6±5.6

Legend: M - Male; F - Female

### Experimental procedures

The evaluation of the adopted experimental procedures is presented in Table 2. Climatic chambers were the most frequent experiment environment (Bogdan, 2011; Liu et al., 2015; Liu et al., 2011; Yao et al., 2007), and also a simulated aircraft cabin was considered (Fang et al., 2018). The acclimatisation of subjects in the local climatic conditions or previous to the experiments is referred to in two of the articles (Bogdan, 2011; Liu et al., 2015). Recommendations regarding behaviour before the experiments are presented in all articles, except for Bogdan (2011) and Fang et al. (2018). The review also assessed the experimental procedures adopted in the determination of the mean local skin temperature (Table 3). Skin temperatures were measured at a variety of measuring points over the reviewed articles. However, only in the work of Bogdan (2011), the skin temperature sensors were positioned in accordance with the ISO standard 9886:2004 (ISO, 2004). The calibration and level of precision of the test system are reported in most articles (Fang et al., 2018; Liu et al., 2015; Liu et al., 2011; Yao et al., 2007).

### Assessment of thermal comfort

Table 4 assess the strategy adopted to assess thermal comfort through the skin temperature measurement in the reviewed articles. The thermal sensation seven-point scale, proposed by ASHRAE (2010) and harmonised in the ISO 7730:2005 (ISO, 2005) for the assessment of thermal sensation was applied in articles. All articles assessed local discomfort or thermal sensation (Yao



et al., 2007; Bogdan, 2011; Liu et al., 2011; Liu et al., 2015; Fang et al., 2018). During experiments, it was also verified whether the subjects were sweating or shivering to verify if the thermoregulatory mechanisms had been activated in Bogdan (2011).

**Table 2.** Environmental conditions in the experiments

Reference	Environment	Air temperature (°C)	Relative Humidity (%)	Air velocity (m/s)	Mean radiant temperature (°C)	Clothing of subjects (clo)
Bogdan, 2011	Climate chamber	15; 20; 25; 30; 35*	50*	0.05*	Close to air temperatures in range of 0.1°C	0.76 ± 0.04 (winter); 0.44 ± 0.02 (summer); 0.04 (semi-nude)
		26.07±0.08	60.71±1.23	0.1±0.01		
		26.08±0.05	61.59±0.43	0.11±0.03		
Fang et al., 2018	Simulated aircraft cabin	26.20±0.09	62.14±0.86	0.11±0.03	Not reported	0.5
		28.17±0.11	61.79±0.99	0.09±0.02		
		28.04±0.08	60.94±0.59	0.1±0.02		
		28.03±0.07	60.05±0.68	0.12±0.01		
		21.2±0.1	42.6±1.2			
Liu et al., 2011	Climate chamber	24.0±0.0	50.6±1.3	<0.05*	21.8±0.1	0.3
		26.0±0.1	56.3±1.2		24.7±0.1	
		29.0±0.0	56.9±1.0		29.5±0.1	
		21.2±0.1	42.6±1.2		21.8±0.1	
Liu et al., 2015	Climate chamber	24.0±0.0	50.6±1.3	0.023±0.002	24.7±0.1	0.3
		26.0±0.1	56.3±1.2	0.019±0.002	26.5±0.1	
		29.0±0.0	56.9±1.0	0.021±0.001	29.5±0.1	
		21.3±0.1	63±3%	0.09±0.01		
Yao et al., 2007	Climate chamber	24.4±0.1	62±3%	0.13±0.02	Not reported	0.378
		26.2±0.2	58±5%	0.11±0.02		
		29.3±0.2	60±4%	0.14±0.02		

\*Standard deviation not reported

**Table 3.** Experimental procedures for skin temperature measurement

Reference	Position	Instrumentation	Measuring points	Location of sensors	Skin temperature parameter (°C)
Bogdan, 2011	Standing	Not specified	14	Forehead, neck, right scapula, left chest, right arm, left arm, left hand, abdomen, paravertebral, right thigh, left thigh, right shin, left calf, right instep	Mean local skin temperature values reported in the graphics
Fang et al., 2018	Seating	MP150 16 channel physiological signal recording system (BIOPAC)*	8	Forehead, chest; back, right upper arm, right forearm, right hand, right thigh, right calf	Mean skin temperature: 33-35
Liu et al., 2011	Lying	Copper-constantan thermocouples linked to a multi-channel data collector with internal reference junction (Keithley Instruments)	21	Forehead, left cheek, left neck, right upper arm, left elbow, left forearm, left palm, right hand, left hand, left back, left chest, left lumbar, left abdomen, left buttocks, anterior thigh, posterior thigh, anterior calf, posterior calf, left foot, right foot, left sole	Mean skin temperature: calculated
Liu et al., 2015	Lying		10	Forehead, chest, upper arm, back, abdomen, elbow, hand, anterior thigh, anterior calf, foot	Mean skin temperature: 32.6–33.7
Yao et al., 2007	Lying	Copper-constantan thermocouples	16	Forehead, cheek, chest, upper arm, abdomen, forearm, hand, anterior thigh, anterior calf, foot, neck, scapula, lumbar, posteromedial thigh, posterior calf, anterior-medial thigh	Mean skin temperature: 32.7–33.5

\*The system consisted of a host computer, temperature amplifier and temperature sensors

**Table 4.** Assessment of thermal comfort

Reference	Thermal sensation	Type of assessment	Other assessment
Bogdan, 2011	ASHRAE Seven-point thermal sensation scale	Scale applied to 18 different body parts	Included identification of shivering and skin dampness
Fang et al., 2018	ASHRAE Seven-point thermal sensation scale	Scale applied to 3 different body parts	Considered seven-point air movement sensation scale: -3 (too still) to (+3) (too windy)
Liu et al., 2011	ASHRAE Seven-point thermal sensation scale	Not applied to a specific body part	Assessed thermal comfort in two levels: comfortable or uncomfortable; Included question about sweating
Liu et al., 2015	ASHRAE Seven-point thermal sensation scale	Not applied to a specific body part	Assessed thermal comfort in three levels: cool discomfort, comfort, and warm discomfort
Yao et al., 2007	ASHRAE Seven-point thermal sensation scale	Applied both to the overall body and 8 body parts	Considered five-point thermal comfort scale: +4 (very comfortable) to -4 (very uncomfortable)

### Comparison of results

A comparison across the reviewed articles is difficult due to the variety of the adopted experimental conditions, particularly the environmental conditions and measurement points. Besides, the assessment of thermal comfort was not coincident over the articles, which makes it difficult to compare the results. However, all the reviewed articles stated that the thermal sensation or thermal comfort is closely related to the skin temperature of the body (Yao et al., 2007; Bogdan, 2011; Liu et al., 2011; Liu et al., 2015; Fang et al., 2018). Differences in mean skin temperature were found between males and females at the same thermal comfort level (Liu et al., 2015; Liu et al., 2011; Yao et al., 2007). The mean skin temperature of female subjects was smaller than the mean skin temperature of male subjects. However, at the level of warm discomfort, the mean skin temperature was almost the same for males and females (Liu et al., 2015; Liu et al., 2011; Yao et al., 2007). Regarding the environmental conditions, the environmental air temperature was considered the most important environmental factor affecting the human thermal comfort in Liu et al. (2011) and Liu et al. (2015). At an air temperature of 21°C, most subjects felt uncomfortable with the sensation of cool or cold; at an air temperature of 29°C, most subjects felt uncomfortably warm, with sweat at the hands, forehead, the chest and back. In the air temperatures of 24°C and 26°C, all subjects felt thermal comfortable (Liu et al., 2011; Liu et al., 2015). The systematic review demonstrated that skin temperature is a good parameter to determine the thermal sensation vote and therefore, to assess thermal comfort in the whole body or specific parts of the body. From the articles it was possible to establish the connections: skin temperature and the thermal sensation (overall or local) regardless of being in the whole body or just specific regions, and the mean skin temperature with thermal sensation vote or thermal comfort level (Liu et al., 2011; Fang et al., 2018; Liu et al., 2015). To determine overall thermal comfort of the body, only the forehead, chest and abdomen appeared to be the best measuring points, with the highest correlation between thermal sensation and skin temperature (Bogdan 2011). This finding is in line with the ones reported by Fang et al. (2018) where the contribution of the upper body segments to the state of overall thermal comfort was more significant when compared to the lower body parts. The differentiation of comfort regarding skin temperature in different body segments was also observed in Yao et al. (2007).

### **CONCLUSIONS**

This short systematic review sought to provide contributions to assess the linkage of thermal comfort and skin temperature in human subjects. This paper showed that skin temperature is a good indicator to determine the thermal sensation in specific parts of the body, being possible

to establish a linear relationship between thermal sensation and skin temperature responses. A limitation of the findings of the selected articles is that all of them make use of a small population sample, which reflects into low statistical confidence of the obtained results. Also, the articles did not present the results for skin temperature at the time of thermal comfort (direct reporting). The reviewed articles have often considered different experimental procedures, which makes it challenging to conduct a fair comparison between the results. Future studies should be conducted considering more uniform procedures based on international standards, with the opportunity to expand the sampled population and conduct experiments considering different target groups, such as children or the elderly, to identify whether the prediction of the thermal comfort based on skin temperatures present the same trends when compared to the healthy adult population.

## References

- Allan, J. R. (1973). The Effects of Core Temperature Elevation and Thermal Sensation on Performance. *Ergonomics*, 16(2), 189-196. doi: 10.1080/00140137308924495
- ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), 2010. ANSI/ASHRAE Standard 55-2010. Thermal Environmental Conditions for Human Occupancy. AHSRAE, USA.
- Bogdan, A. (2011). Case Study Assessment of Local and General Thermal Comfort by Means of Local Skin Temperature. *International Journal of Ventilation*, 10(3), 291-300. doi: 10.1080/14733315.2011.11683956
- Charkoudian, N. (2003). Skin Blood Flow in Adult Human Thermoregulation: How It Works, When It Does Not, and Why. *Mayo Clinic Proceedings*, 78(5), 603-612. doi: 10.4065/78.5.603
- De Dear, R. J., Ring, J. W., & Fanger, P. O. (1993). Thermal sensations resulting from sudden ambient temperature changes. *Indoor air*, 3(3), 181-192.
- Fang, Z., Liu, H., Li, B., Cheng, Y. (2018). Thermal comfort and skin temperature responses to the supplied air from personal air nozzles in aircraft cabins. *Indoor and Built Environment*, 27(6), 831-845. doi: 10.1177/1420326X17692853
- Grant, M. J., Booth, A. (2009). A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal*, 26(2), 91-108. doi: 10.1111/j.1471-1842.2009.00848.x
- ISO (International Organization for Standardization), 1998. ISO 7726:1998 - Ergonomics of the thermal environment -- Instruments for measuring physical quantities. International Organization for Standardization, Switzerland.
- ISO, 2004. ISO 9886:2004 - Ergonomics - Evaluation of thermal strain by physiological measurements. International Organization for Standardization, Switzerland.
- ISO, 2005. ISO 7730:2005 - Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria. International Organization for Standardization, Switzerland.
- Liu, W., Lian, Z., Deng, Q. (2015). Use of mean skin temperature in evaluation of individual thermal comfort for a person in a sleeping posture under steady thermal environment. *Indoor and Built Environment*, 24(4), 489-499. doi: 10.1177/1420326X14527975
- Liu, W., Lian, Z., Deng, Q., Liu, Y. (2011). Evaluation of calculation methods of mean skin temperature for use in thermal comfort study. *Building and Environment*, 46(2), 478-488. doi: 10.1016/j.buildenv.2010.08.011
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., and the, P. G. (2009a). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *Annals of Internal Medicine*, 151(4), 264-269. doi: 10.7326/0003-4819-151-4-200908180-00135
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., The, P. G. (2009b). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLOS Medicine*, 6(7), e1000097. doi: 10.1371/journal.pmed.1000097
- Parsons, K., 2003. Human Thermal Environments, 2nd ed. Taylor & Francis, United Kingdom.
- Vasmatazidis, I. (2003). Effects of heat stress on cognitive performance: the current state of knowledge AU - Hancock, P. A. *International Journal of Hyperthermia*, 19(3), 355-372. doi: 10.1080/0265673021000054630
- Yao, Y., Lian, Z., Liu, W., Shen, Q. (2007). Experimental Study on Skin Temperature and Thermal Comfort of the Human Body in a Recumbent Posture under Uniform Thermal Environments. *Indoor and Built Environment*, 16(6), 505-518. doi: 10.1177/1420326X07084291

## A short review on physiological monitoring during working activities

D. Bustos<sup>1</sup>, J. C. Guedes<sup>2</sup>, J. Torres Costa<sup>3</sup>

<sup>1</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), University of Porto, PT ([denissebustossandoval@gmail.com](mailto:denissebustossandoval@gmail.com)) ORCID 0000-0002-4942-7625, <sup>2</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), University of Porto, PT ([jccg@fe.up.pt](mailto:jccg@fe.up.pt)) ORCID 0000-0003-2367-2187, <sup>3</sup>Faculty of Medicine, University of Porto, PT ([zecatoco@sapo.pt](mailto:zecatoco@sapo.pt))  
[https://doi.org/10.24840/978-972-752-260-6\\_0088-0095](https://doi.org/10.24840/978-972-752-260-6_0088-0095)

### Abstract

**Introduction:** Temperature extremes, load carriage, inadequate sleep, information overload, dehydration, and impaired nutrition, are common risks associated with many occupational activities, including those for whom optimal functioning is critical at all times. These safety-sensitive occupations include firefighters, first responders, police officers, physicians, airline pilots, soldiers, and those operating heavy machinery. In any of these cases, the resulting interaction between occupational stress and individual susceptibility to illness demands careful management. This represents a dual challenge to organizations responsible for the well-being of personnel who engage in strenuous tasks, imposing requirements to be vigilant for or, even, curtail situations that result in high physiological strain. The emergence of wearable physiological monitoring technologies could prove advantageous in this regard. **Purpose:** To our knowledge, no review gathering the applicability of these systems within occupational groups has been conducted. Therefore, this review aims to summarize current progress in the development of wearable physiological monitoring systems for occupational applications. **Methodology:** Five databases were accessed (SCOPUS, PubMed, Science Direct, Academic Search Complete and Web of Science) and a total of 12 keywords were combined to develop a search on journal articles from January 2014 to January 2019. Study eligibility based on active workers participants and assessment methods not interfering with normal tasks development and involving harmless procedures. Furthermore, investigations conducted with prognostic health-related goals were filtered. **Results and Discussion:** Nineteen studies were analyzed in this review. In general, their goals were directed to quantifying the impact of specific physically demanding tasks or validating newly proposed methods for classifying the effects of different levels and workloads of occupational tasks based on workers' physiology. Identified occupational groups mostly included construction workers, drivers, and firefighters. Retrieved papers highlighted the importance of field monitoring to provide a chance to timely detect any abnormal condition in the worker's physiology that might be affected by working conditions or environmental stresses. **Conclusions:** Wearable sensors proved to be a valid tool for assessing physiological status in simulated and real working environments. Future research perspectives should be focused on validation of standardized procedures within bigger samples and involving a variety of safety-sensitive professions. Finally, based on physiology and novel computational techniques, it was observed that further developments should be concentrated in the algorithms that allow low-cost sensors to be used in operational settings to provide the continuous subjects' status promoting to sustain their given tasks in a safer and healthier way.

**Keywords:** Physiological monitoring, Occupational health, Review.

### INTRODUCTION

Athletes must compete with very high metabolic demands in outdoor temperature extremes. Miners and steelworkers are exposed to high heat conditions (Butlewski, Dahlke, Drzewiecka, & Pacholski, 2015; Chen, Chen, Yeh, Huang, & Mao, 2003). Firefighters, first responders, and soldiers often wear personal protective equipment that imposes additional thermal burdens from insulation and extra carried weight (Buller, Welles, & Friedl, 2018) while exposed to extreme environments, inadequate sleep, information overload, dehydration and even impaired nutritional status (Lieberman et al., 2005). As a result, decrements in workplace performance, health, and safety are typically encountered. This represents a dual challenge to organizations responsible for the well-being of personnel who engage in strenuous tasks, imposing requirements to be vigilant for, or even curtail, situations that may result in high physiological strain in healthy personnel and also to identify and protect vulnerable individuals. The emergence and increasing interest in wearable physiological monitoring devices can help to address this challenge but requires that the right questions are asked in sourcing, developing, validating and applying such technologies (Stacey, Hill, & Woods, 2018). Wearable physiological monitoring can provide predictions about an individual's health and performance from their real-time physiological state (Raskovic, Martin, & Jovanov, 2004). However, available systems

mostly do not satisfy the requirements for occupational use. Even when they offer more than raw physiological data, computed information is usually based on proprietary algorithms that cannot be properly reviewed and validated. The critical component of a real-time physiological monitoring system is the algorithm that turns data into useful and actionable knowledge for a worker or a small unit leader. Useful information from these systems is defined as vitally important alerts that can be acted on to affect the outcome of operations and improve safety and effectiveness (Friedl, 2018). To our knowledge, no comprehensive search of the literature has been developed in this regard. Thus, a review is proposed to find relevant information about the current progress of these physiological monitoring systems and their potential applications for occupational settings.

## METHODOLOGY

This review was limited to research articles and articles in press published in peer-reviewed journals in the English language. It was conducted in Scopus, PubMed, Science Direct, Academic Search Complete and Web of Science databases and narrowed to articles published between January 2014 and January 2019. The 12 identified keywords were combined as follows:

(( ("physiolog\*monitor\*") OR ("noninvasive monitor\*") OR ("medical monitor\*") OR ("wearable sens\*")) AND ((assessment) OR (occupational) OR (model) OR (fatigue) OR (algorithm) OR (worker) OR (training) OR ("physical exertion"))))

The search focused on investigations developed within working-age active participants and incorporated both females and males with no additional restrictions. Study selection was based on three phases of exclusion: applying filters from databases, eliminating repeated records and analyzing each article individually to remove studies in which no prognostic health objectives were pursued, procedures were not developed within active working-age subjects, or no non-invasive methods were used. Finally, inclusion criteria were those investigations in which non-invasive objective physiological assessment methods were applied, and measurements were developed during real or simulated working activities.

## RESULTS

Nineteen studies were selected for this review. Their primary characteristics are summarized in Table 1. In total, they included 406 participants. From them, 17 out of the 19 (two using the same sample (Pancardo, Acosta, Hernandez-Nolasco, Wister, & Lopez-de-Ipina, 2015; Pancardo, Hernández-Nolasco, & Acosta-Escalante, 2018)) indicated gender distributions, denoting 12.86% of women and 87.14% of men participants. All subjects were part of the healthy active working population. Mean age values ranged from 22.7 to 43.8 years old. All used comparisons with previous or basal levels of the same subjects. No control group was observed. Occupational groups were diverse: four studies were developed within construction workers (Antwi-Afari, Li, Seo, & Wong, 2018; Aryal, Ghahramani, & Becerik-Gerber, 2017; Hwang, Seo, Jebelli, & Lee, 2016; Lee, Lin, Seto, & Migliaccio, 2017), three involved drivers (Boon-Giin, Boon-Leng, & Wan-Young, 2014; Choi, Koo, Seo, & Kim, 2018; Fu, Wang, & Zhao, 2016), two included firefighting personnel (Davis & Gallagher, 2014; Sol, Ruby, Gaskill, Dumke, & Domitrovich, 2018) and, office workers (Boerema, Essink, Toenis, van Velsen, & Hermens, 2016), pilots (Hidalgo-Munoz et al., 2018), custodial staff (Pancardo et al., 2015; Pancardo et al., 2018), operators from drillship (Mehta et al., 2017), ironworkers (K. Yang, Ahn, Vuran, & Aria, 2016), manufacturing workers (Baghdadi, Megahed, Esfahani, & Cavuoto, 2018) and law enforcement personnel (Yokota, Karis, & Tharion, 2014) were observed in one paper each. Two investigations, in which a specific

profession was not defined were also evidenced: one reported a sample of cold-exposed workers (Austad, Wiggen, Færevik, & Seeberg, 2018) and the other examined a multidisciplinary group of postal, construction and office workers and drivers (L. Yang et al., 2018). Lastly, observing the context in which assessments were carried out, most of them (10 studies) considered real working scenarios (Davis & Gallagher, 2014; Fu et al., 2016; Hwang et al., 2016; Lee et al., 2017; Mehta et al., 2017; Pancardo et al., 2015; Pancardo et al., 2018; Sol et al., 2018; L. Yang et al., 2018; Yokota et al., 2014) while 7 were developed through laboratory trials (Antwi-Afari et al., 2018; Aryal et al., 2017; Austad et al., 2018; Baghdadi et al., 2018; Boon-Giin et al., 2014; Choi et al., 2018; Hidalgo-Munoz et al., 2018). Only two performed measurements contrasting real and experimental contexts (Boerema et al., 2016; L. Yang et al., 2018).

**Table 1.** Studies characteristics

Author (year)	Approach	Sample	Assessed parameters	Wearable sensors	Data processing and analysis
(Antwi-Afari et al., 2018)	A novel methodology to classify loss-of-balance events.	10 construction workers	Foot plantar pressure distribution.	Moticon SCIENCE (Moticon GmbH, Munich, Germany)	Supervised machine learning algorithms to learn the unique foot plantar pressure patterns.
(Aryal et al., 2017)	A novel approach for real-time monitoring.	12 construction workers	HR, Tsk, RPE.	Heart rate monitor, EEG sensor and a construction safety helmet fitted with 4 infrared temperature sensors.	Several supervised machine learning algorithms tested to explore the applicability of the monitored variables for fatigue predictions.
(Austad et al., 2018)	Cold stress assessment.	11 cold exposed workers	HR, T, Tsk, VO <sub>2</sub> , T, RH, activity.	Smart jacket with integrated sensors (Tsk, movement, temperature, humidity), custom-made sensor belt (HR, Tsk, air humidity and temperature on the chest/back). Indirect calorimetry (Oxycon Pro, Jaeger, Hoechberg, Germany)	Descriptive statistics at group and individual levels.
(Baghdadi et al., 2018)	Method to classify non-fatigued vs. fatigued states	20 manufacture workers	ACC.	IMU Shimmer3 (Shimmer, Dublin, Ireland)	Matlab R2015b. Simple machine learning algorithm.
(Boerema et al., 2016)	Sedentary behavior profile.	27 office workers	Activity.	Promove 3D activity sensor	Statistical analysis of variances (ANOVA)
(Boon-Giin et al., 2014)	Method to classify driving mental fatigue.	20 drivers	EEG, respiration signals.	EEG sensor, respiration sensor, microprocessor, Bluetooth module, Google Nexus 5	Support vector machine classifier
(Choi et al., 2018)	Proposal of wearable device-based system.	28 drivers	Photoplethysmogram, galvanic skin response, rate of rotation, T, ACC.	New device parts: for PPG (SFH7050 OSRAM, AFE4404 Texas Instruments) accel and gyro (MPU-6050 InvenSense), temperature (HDC1008 Texas Instruments), MCU (MSP430G2553 Texas Instruments).	A support vector machine-based classification method.
(Davis & Gallagher, 2014)	Quantify physiological demands.	25 firefighter trainees	HR, air consumption, body part discomfort.	Garmin Forerunner 110 monitors (Garmin International, Olathe, KS)	Descriptive statistics.
(Fu et al., 2016)	Dynamic fatigue detection model.	12 professional long-distance bus drivers	EEG, electromyogram and respiration signals.	Biofeedback 2000 x-pert system	A dynamic fatigue detection model based

Author (year)	Approach	Sample	Assessed parameters	Wearable sensors	Data processing and analysis
					on Hidden Markov Model (HMM).
(Hidalgo-Munoz et al., 2018)	Determine cardiovascular, emotional and cognitive correlations.	20 private pilots	HR, HRV.	BrainVision Recorder 1,21 (Brain Products GmbH, Gilching, Germany)	Matlab 2016a, statistical analysis on STATISTICA version 12.
(Hwang et al., 2016)	Accuracy of photoplethysmogram sensor.	11 construction workers (drywall, masonry, electrical operations).	HR	photoplethysmography (PPG) sensor embedded in a wristband-type activity tracker	Two methods for data synchronization: manual comparison with two smartphone applications (i.e., Polar Beat and Wahoo Fitness) and phase-shifting algorithms (Hampel filter)
(Lee et al., 2017)	Reliability of wearable sensors.	6 roofers.	HR, HRV, ACC, EE, metabolic equivalents, sleep quality.	Zephyr BioharnessTM 3 sensors (Medtronic, Dublin, Ireland). ActiGraph GT9X unit (ActiGraph, LLC, Pensacola, Florida)	Algorithms from ActiLife (version 6.13.1). Analysis of variance ANOVA.
(Mehta et al., 2017)	Comparison of objective and subjective fatigue assessment methods.	10 operators from drillship.	HR, ACC.	EQ02 LifeMonitor, Equivital™, Cambridge, UK.	Separate mixed effects analyses of variance (ANOVA), Pearson's correlations.
(Pancarado et al., 2015)	Design and development of real-time personalized monitoring for objective estimation of Occupational Heat Stress	20 cleaning staff	Movements, HR, T, humidity.	Samsung Galaxy S4 (Android 4.2.2 Jelly Bean Operation System, octa-core chipset, 1.6-GHz Quad + 1.2 GHz Quad CPU) Smartphones containing an accelerometer, STMicroelectronics LSM 330, and a Sensirion SHTC1 humidity and temperature sensor. Gene Activ accelerometer wristband: ZephyrWireless Bluetooth Heart Rate Monitor for Android and Windows Phone 8, an Omron Sphygmomanometer Model HEM-742INT, a Basis B1 Fitness Wristband and a Multifunction Digital Thermometer OBI 292312.	An application to estimate VAM, physical effort, and the workload was developed with the Java 6.0 language using the ADT tool v22.3.0-887826. To analyze the values obtained from the accelerometer MATLAB Version R2014a was used.
(Pancarado et al., 2018)	HR-based personalized method to assess perceived exertion.	20 cleaning staff	HR	Basis B1 Fitness Wristband, Omron Sphygmomanometer Model HEM742INT.	Prototype developed with the Java 6.0 language using the ADT tool v22.3.0-887826; implemented over a Samsung Galaxy S4, an Android 4.2.2(JellyBean) Operation System, an octa-core chipset, and a 1.6GHz Quad+1.2GHz Quad CPU.

Author (year)	Approach	Sample	Assessed parameters	Wearable sensors	Data processing and analysis
(Sol et al., 2018)	Physical demands of hiking in wildland firefighting.	131 wildland firefighters	HR, Tco, speed and elevation gain.	Wireless thermometer capsule (Jonah ingestible sensor, Mini Mitter, Bend, OR), Hidalgo Equivital Physiological Monitor (Equivital, UK).	Independent t tests, two-way analysis of variance (IHC vs Type II and hike types) tests. Data analysis using SPSS (SPSS Inc, Chicago, IL)
(K. Yang et al., 2016)	Method to automatically detect near-miss falls based upon kinematic data	5 ironworkers	kinematic data (acceleration, angular velocity)	wearable inertial measurement units (WIMUs)	Semi-supervised learning algorithm (i.e., one-class support vector machine).
(L. Yang et al., 2018)	Wearable system through a mobile application for assessment of different types and levels of workloads.	8 workers (2 postal workers, 2 construction workers, 2 office workers, 2 drivers)	HR	vest with four texdrones made with conductive Shieldex Fabric P130+B manufactured by STATEX GmbH (Bremen, Germany)	Android-compatible application. Algorithm by Skotte et al. was applied.
(Yokota et al., 2014)	Examine thermal strain levels.	30 law enforcement personnel	HR, Tco.	Chest strap sensor (Equivital™ EQ-01; Hidalgo Ltd., Cambridge, UK).	Statistical analysis.

## DISCUSSION

This review focused on the assessment of continuous physiological responses of occupational tasks. Mostly, studies' goals were directed to quantifying the impact of physically demanding activities or validating newly proposed methods for classifying the effects of different levels and workloads of occupational tasks based on workers' physiology. In general, they highlighted the importance of field monitoring to timely detect any abnormal condition of the worker that might be affected by working or environmental stresses (Hwang et al., 2016). Since most of the investigations were developed within real working environments, the feasibility of performing continuous assessments during regular occupational situations was indeed demonstrated. Among retrieved articles, a variety of occupational groups were assessed. Studied professions included construction workers, drivers, firefighters, pilots, ironworkers, cleaning staff and law enforcement personnel of military sites. The encountered interest on some of these occupations was justified as they correspond to safety-sensitive professions, in which effective human performance is crucial to a successful outcome (Barger, Lockley, Rajaratnam, & Landrigan, 2009). Furthermore, a notable focus was evidenced on construction workers (included in five out of the 19 articles). Construction work typically involves physically demanding tasks performed in harsh environmental conditions, which can cause fatigue and lead to poor judgment, poor quality of work, increased risk of accidents and reduction in productivity (Aryal et al., 2017). Consistently, among retrieved papers, the clear interest was on assessing fatigue (Aryal et al., 2017; Hwang et al., 2016; Lee et al., 2017; L. Yang et al., 2018) and developing methods for preventing risks of accidents (Antwi-Afari et al., 2018). On the other hand, observing monitoring methods (Table 1), several wearable sensors were identified, and their simultaneous use for multivariable measurement was a clear tendency. Noteworthy is the fact that the only wearable system used in more than one selected study was the Equivital LifeMonitor (Hidalgo Ltd., Cambridge, UK). As Mehta et al. (2017) indicated, the validity, reliability, and applicability of this system for sleep and ambulatory monitoring of multiple physiological parameters during construction and firefighting work have been previously demonstrated (Gatti, Schneider, & Migliaccio, 2014; Liu, Zhu, Wang, Ye, & Li, 2013; Savage et al., 2014). Among selected studies, three included this system to obtain physiological data from operators in drillship (Mehta et al., 2017), wildland firefighters (Sol et al., 2018) and law enforcement personnel (Yokota et al., 2014). In all cases it



proved advantageous for obtaining measurements in field conditions and, HR assessment was observed as the focus assessed variable. Thus, it can be inferred that the tendency on the usage of validated procedures is maintained and future perspectives could be oriented to test the other referred methods within bigger samples and during real-life operations. Finally, observing physiological variables, cardiac responses to specific occupational activities were the most considered assessment goal among retrieved papers. HR was included in 11 out of the 19 final articles. Based on current work physiology literature, this can be explained as this variable has shown to be sensitive to changes in physical and mental fatigue (Borg, Hassmén, & Lagerström, 1987; Hankins & Wilson, 1998), as well as sleep and circadian issues (Carney et al., 2014; Kang et al., 2015). Collectively, findings not only suggest the relevance of multivariable approaches that include monitoring of cardiac responses along with validated fatigue indicators (thermal responses and scales of perceived exertion) but also confirm the need of inclusion of other variables such as metabolic equivalents (Lee et al., 2017) and respiratory signals (Boon-Giin et al., 2014; Fu et al., 2016). Finally, despite being assessed in few of the selected articles, approaches such as foot plantar distribution (Antwi-Afari et al., 2018) also proved to be beneficial for prognostic goals in occupational settings and could be included in future research works. Lastly, observing data processing methods, support vector machine classifiers and algorithm-based applications for smartphones suggest the evolution of data management with the tendency of assessing traditional fatigue physiological indicators (HR, acceleration, respiration signals) but through newly available computational techniques.

## CONCLUSIONS

In this review, the evidence of current progress in the development of physiological monitoring systems and their applications for occupational settings is compiled. Selected studies indicate the feasibility of devices using physiological signals to examine the impact of occupational tasks and improve the management of health-related negative consequences in the near future. With a basis in physiology and application of principled computational techniques, it was demonstrated that future perspectives should be focused in the algorithms that allow simple low-cost sensors to be used in operational settings and provide the continuous subjects' status promoting to sustain their given tasks in a safer and healthier way.

## Funding

This work was accomplished during the period of a research scholarship granted by the Doctoral Program of Occupational Safety and Health of the University of Porto.

## References

- Antwi-Afari, M. F., Li, H., Seo, J., & Wong, A. Y. L. (2018). Automated detection and classification of construction workers' loss of balance events using wearable insole pressure sensors. *Automation in Construction*, 96, 189-199. doi:10.1016/j.autcon.2018.09.010
- Aryal, A., Ghahramani, A., & Becerik-Gerber, B. (2017). Monitoring fatigue in construction workers using physiological measurements. *Automation in Construction*, 82, 154-165. doi:10.1016/j.autcon.2017.03.003
- Austad, H., Wiggen, Ø., Færevik, H., & Seeberg, T. M. (2018). Towards a wearable sensor system for continuous occupational cold stress assessment. *Ind Health*, 56(3), 228-240. doi:10.2486/indhealth.2017-0162
- Baghdadi, A., Megahed, F. M., Esfahani, E. T., & Cavuoto, L. A. (2018). A machine learning approach to detect changes in gait parameters following a fatiguing occupational task. *Ergonomics*, 61(8), 1116-1129. doi:10.1080/00140139.2018.1442936

- Barger, L. K., Lockley, S. W., Rajaratnam, S. M., & Landrigan, C. P. (2009). Neurobehavioral, health, and safety consequences associated with shift work in safety-sensitive professions. *Current neurology and neuroscience reports*, 9(2), 155-164. doi:10.1007/s11910-009-0024-7
- Boerema, S. T., Essink, G. B., Toenis, T. M., van Velsen, L., & Hermens, H. J. (2016). Sedentary Behaviour Profiling of OfficeWorkers: A Sensitivity Analysis of Sedentary Cut-Points. *Sensors*, 16(1). doi:10.3390/s16010022
- Boon-Giin, L., Boon-Leng, L., & Wan-Young, C. (2014). Mobile Healthcare for Automatic Driving Sleep-Onset Detection Using Wavelet-Based EEG and Respiration Signals. *Sensors* (14248220), 14(10), 17915-17936. doi:10.3390/s141017915
- Borg, G., Hassmén, P., & Lagerström, M. (1987). Perceived exertion related to heart rate and blood lactate during arm and leg exercise. *European journal of applied physiology and occupational physiology*, 56(6), 679-685. doi:10.1007/BF00424810
- Buller, M. J., Welles, A. P., & Friedl, K. E. (2018). Wearable physiological monitoring for human thermal-work strain optimization. *J Appl Physiol* (1985), 124(2), 432-441. doi:10.1152/jappphysiol.00353.2017
- Butlewski, M., Dahlke, G., Drzewiecka, M., & Pacholski, L. (2015). Fatigue of Miners as a Key Factor in the Work Safety System. *Procedia Manufacturing*, 3, 4732-4739. doi:10.1016/j.promfg.2015.07.570
- Carney, R. M., Steinmeyer, B., Freedland, K. E., Stein, P. K., Hayano, J., Blumenthal, J. A., & Jaffe, A. S. (2014). Nocturnal patterns of heart rate and the risk of mortality after acute myocardial infarction. *American heart journal*, 168(1), 117-125. doi:10.1016/j.ahj.2014.04.012
- Chen, M.-L., Chen, C.-J., Yeh, W.-Y., Huang, J.-W., & Mao, I.-F. (2003). Heat stress evaluation and worker fatigue in a steel plant. *AIHA Journal*, 64(3), 352-359.
- Choi, M., Koo, G., Seo, M., & Kim, S. W. (2018). Wearable Device-Based System to Monitor a Driver's Stress, Fatigue, and Drowsiness. *IEEE Transactions on Instrumentation & Measurement*, 67(3), 634-645. doi:10.1109/TIM.2017.2779329
- Davis, J., & Gallagher, S. (2014). Physiological demand on firefighters crawling during a search exercise. *International Journal of Industrial Ergonomics*, 44(6), 821-826. doi:10.1016/j.ergon.2014.10.001
- Friedl, K. E. (2018). Military applications of soldier physiological monitoring. *J Sci Med Sport*, 21(11), 1147-1153. doi:10.1016/j.jsams.2018.06.004
- Fu, R., Wang, H., & Zhao, W. (2016). Dynamic driver fatigue detection using hidden Markov model in real driving condition. *Expert Systems with Applications*, 63, 397-411. doi:10.1016/j.eswa.2016.06.042
- Gatti, U. C., Schneider, S., & Migliaccio, G. C. (2014). Physiological condition monitoring of construction workers. *Automation in Construction*, 44, 227-233.
- Hankins, T. C., & Wilson, G. F. (1998). A comparison of heart rate, eye activity, EEG and subjective measures of pilot mental workload during flight. *Aviation, space, and environmental medicine*, 69(4), 360-367.
- Hidalgo-Munoz, A. R., Mouratille, D., Matton, N., Causse, M., Rouillard, Y., & El-Yagoubi, R. (2018). Cardiovascular correlates of emotional state, cognitive workload and time-on-task effect during a realistic flight simulation. *Int J Psychophysiol*, 128, 62-69. doi:10.1016/j.ijpsycho.2018.04.002
- Hwang, S., Seo, J., Jebelli, H., & Lee, S. (2016). Feasibility analysis of heart rate monitoring of construction workers using a photoplethysmography (PPG) sensor embedded in a wristband-type activity tracker. *Automation in Construction*, 71(Part 2), 372-381. doi:10.1016/j.autcon.2016.08.029
- Kang, D., Kim, Y., Kim, J., Hwang, Y., Cho, B., Hong, T., . . . Lee, Y. (2015). Effects of high occupational physical activity, aging, and exercise on heart rate variability among male workers. *Annals of occupational and environmental medicine*, 27(1), 22. doi:10.1186/s40557-015-0073-0
- Lee, W., Lin, K. Y., Seto, E., & Migliaccio, G. C. (2017). Wearable sensors for monitoring on-duty and off-duty worker physiological status and activities in construction. *Automation in Construction*, 83, 341-353. doi:10.1016/j.autcon.2017.06.012

- Lieberman, H. R., Bathalon, G. P., Falco, C. M., Kramer, F. M., Morgan III, C. A., & Niro, P. (2005). Severe decrements in cognition function and mood induced by sleep loss, heat, dehydration, and undernutrition during simulated combat. *Biological psychiatry*, 57(4), 422-429.
- Liu, Y., Zhu, S. H., Wang, G. H., Ye, F., & Li, P. Z. (2013). Validity and reliability of multiparameter physiological measurements recorded by the Equivital LifeMonitor during activities of various intensities. *J Occup Environ Hyg*, 10(2), 78-85.
- Mehta, R. K., Peres, S. C., Kannan, P., Rhee, J., Shortz, A. E., & Mannan, M. S. (2017). Comparison of objective and subjective operator fatigue assessment methods in offshore shiftwork. *Journal of Loss Prevention in the Process Industries*, 48, 376-381. doi:10.1016/j.jlp.2017.02.009
- Pancardo, P., Acosta, F. D., Hernandez-Nolasco, J. A., Wister, M. A., & Lopez-de-Ipina, D. (2015). Real-Time Personalized Monitoring to Estimate Occupational Heat Stress in Ambient Assisted Working. *Sensors*, 15(7), 16956-16980. doi:10.3390/s150716956
- Pancardo, P., Hernández-Nolasco, J. A., & Acosta-Escalante, F. (2018). A Fuzzy Logic-Based Personalized Method to Classify Perceived Exertion in Workplaces Using a Wearable Heart Rate Sensor. *Mobile Information Systems*, 2018. doi:10.1155/2018/4216172
- Raskovic, D., Martin, T., & Jovanov, E. (2004). Medical monitoring applications for wearable computing. *The computer journal*, 47(4), 495-504.
- Savage, R. J., Lord, C., Larsen, B. L., Knight, T. L., Langridge, P. D., & Aisbett, B. (2014). Firefighter feedback during active cooling: A useful tool for heat stress management? *Journal of thermal biology*, 46, 65-71.
- Sol, J. A., Ruby, B. C., Gaskill, S. E., Dumke, C. L., & Domitrovich, J. W. (2018). Metabolic Demand of Hiking in Wildland Firefighting. *Wilderness Environ Med*, 29(3), 304-314. doi:10.1016/j.wem.2018.03.006
- Stacey, M. J., Hill, N., & Woods, D. (2018). Physiological monitoring for healthy military personnel: British Medical Journal Publishing Group.
- Yang, K., Ahn, C. R., Vuran, M. C., & Aria, S. S. (2016). Semi-supervised near-miss fall detection for ironworkers with a wearable inertial measurement unit. *Automation in Construction*, 68, 194-202. doi:10.1016/j.autcon.2016.04.007
- Yang, L., Lu, K., Diaz-Olivares, J. A., Seoane, F., Lindecrantz, K., Forsman, M., . . . Eklund, J. A. E. (2018). Towards Smart Work Clothing for Automatic Risk Assessment of Physical Workload. *IEEE Access*, 6, 40059-40072. doi:10.1109/ACCESS.2018.2855719
- Yokota, M., Karis, A. J., & Tharion, W. J. (2014). Thermal-work strain in law enforcement personnel during chemical, biological, radiological, and nuclear (CBRN) training. *Int J Occup Environ Health*, 20(2), 126-133. doi:10.1179/2049396714y.0000000056

## A comparison of energy expenditure equations for basal-equivalent activities

D. Bustos<sup>1</sup>, A. D. Lucena<sup>2</sup>, J. C. Guedes<sup>3</sup>

<sup>1</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), University of Porto, PT (denissebustossandoval@gmail.com) ORCID 0000-0002-4942-7625, <sup>2</sup>Federal Rural University of Semiarid, BR (andre.lucena@ufersa.edu.br) ORCID 000-0003-0181-4260, <sup>3</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), University of Porto, PT (jccg@fe.up.pt) ORCID 0000-0003-2367-2187  
[https://doi.org/10.24840/978-972-752-260-6\\_0096-0102](https://doi.org/10.24840/978-972-752-260-6_0096-0102)

### Abstract

**Introduction:** Resting energy expenditure (REE) represents the largest component of total energy expenditure and is a major contributor to energy balance. Over the past several decades, numerous REE equations have been developed targeted to different population groups. However, the generation of standardized equations for predicting energy expenditure, to be applied to every healthy individual, is still subject to research. **Purpose:** This study aims to test existing predictive equations for basal energy requirements and based on a comparison of their results and measured values, to determine the most appropriate to the characteristics of the studied group. **Methodology:** Thirty participants (age 30,37 ± 5,50) performed a sequence of five activities chosen to represent basal, light and moderate intensities. The included three basal-equivalent tasks were analyzed in this study. During each trial, oxygen consumption was measured by a portable metabolic system (K4b<sup>2</sup>). From a previously developed literature research, equations were selected to estimate energy requirements. Calculations and values obtained from oximetry were compared. **Results and Discussion:** Retrieved predictive equations were filtered to 21 relevant equations from 15 authors. When observing general results, most participants showed the equation proposed by Korth (based on weight, height, sex, and age) to be the one predicting values with a better approximation to K4b<sup>2</sup>, followed by the Haaf&Weijs' equation, based on fat-free mass (FFM). From the individual analysis, Korth's equation proved to work well for men in most cases and poorly for women. Correspondingly, Haaf&Weijs equation gave better results for females. Specifically, better approximations were obtained within males participants. Finally, the associated deviations from measured values indicate more reliable results than a Level 1 (two with better accuracy than a Level 2) of the assessment approaches, for energy consumption while working, referred in the ISO 8996:2004 standard. **Conclusions:** Through this study, Korth (based on weight, height, sex, and age) and Haaf&Weijs (based on FFM) equations proved to be the most accurate. As a result, since body composition measurement is not always possible, the equation of Korth is advised for use in a young subjects' sample with similar overall characteristics to the sample hereby presented. Future studies should be developed to test equations within bigger samples and propose a new regression model that better adapts to the studied population.

**Keywords:** Resting energy expenditure, Energy requirements, Energy expenditure estimations.

### INTRODUCTION

The accurate prediction of energy requirements for healthy individuals has many useful applications (Mifflin et al., 1990). Various studies associated with energy expenditure have been conducted within different contexts. From the occupational perspective, it has also been proven of great utility for ergonomics, safety, and health of workers (Lucena, Guedes, Vaz, & Silva, 2018). Specifically, resting energy expenditure (REE) contributes to 60-70% of daily energy requirements. REE is the maintenance energy cost of the body in rest under steady state conditions. This is different from the minimal energy cost. Energy expenditure can, for example, be lower during sleep or during undernutrition (ten Haaf & Weijs, 2014). REE can be measured through indirect calorimetry or estimated using predictive equations. The gold standard to determine the REE is the measurement by indirect calorimetry (ISO, 2004; Lucena et al., 2018). However, procedures for direct measurements are complex, expensive and not feasible for frequent and timely individual use (Sabounchi, Rahmandad, & Ammerman, 2013; ten Haaf & Weijs, 2014). As a result, several mathematical equations, mostly developed by regression methods, have been adopted as a major technique for this matter. Nevertheless, there is not an agreement on which equation is most suitable to which situation or to which population's characteristics. Therefore, this study aims to validate existing resting energy expenditure

predictive equations and, based on obtained results, to identify the equations that better estimate energy requirements for every tested situation.

## METHODOLOGY

Most of the experiments were performed at the Laboratory on Prevention of Occupational and Environmental Risks (PROA) at the Faculty of Engineering of the University of Porto, while the rest were executed at the Faculty facilities. The volunteers were fully informed of the details of the experimental procedures and were briefed on purpose, potential risks and benefits of the experiences. Written consent was read and signed by them prior to starting the trials.

### Participants

Thirty participants volunteered for the study. Their physical characteristics are summarized in Table 1.

**Table 1.** Subjects' characteristics

Variables	Total (n 30)		Male (n 15)		Female (n 15)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	30,37	5,50	31,00	6,23	29,73	4,79
Height (cm)	171,07	9,78	177,27	8,11	164,87	7,08
Weight (kg)	70,73	14,19	79,21	13,85	62,26	8,47
BMI (kg/m <sup>2</sup> )	23,86	3,67	24,86	3,57	22,85	3,59
FFM (kg)	52,96	13,83	62,96	12,09	42,95	5,95

### Materials and equipment

The experiments were mostly conducted inside a climatic chamber (FITOCLIMA 25000EC20). Body composition was assessed using bioelectrical impedance analysis (Body Composition Analyzer InBody230). Energy expenditure (EE) was measured from pulmonary gas exchange using a breath-by-breath portable gas analyzer (Cosmed K<sub>4</sub>b<sup>2</sup>, Rome, Italy).

### Experimental design

Before testing, participants had their height and weight measured (in light clothing, without shoes). Later, they performed various lifestyle and simulated working activities. Activities were chosen to test the multiple equations found in the literature at the time of verifying the relevance of the measurements for occupational settings. The designed protocol has 5 activities (Table 2). Nevertheless, this present work will focus on the three found to be equivalent to basal conditions (1, 2, 5) aiming to test the applicability of REE equations (found in the available scientific literature) to the studied population's characteristics.

### Literature search and filtering

A comprehensive search of the literature was performed to identify all available studies that predict energy expenditure, based on anthropometric data and actigraphy, and develop an investigation within healthy participants. Consulted databases included: Academic Search Complete, Scopus, Web of Science, Science Direct, PubMed, Francis and Taylor, and Medline. Search terms were selected so that any publication, which finds a prediction model for energy expenditure, is included. Retrieved articles were reviewed in two steps. First, abstracts were reviewed and items not fitting were excluded. Then, the full-text for the remaining articles were obtained and analyzed to select the articles that included an equation based on the above

criteria. In a parallel process, reference tracking helped to identify additional studies not retrieved through an automated search.

**Table 2.** Protocol of activities.

Activity Sequence	Description	Duration (min)	Type of Activity
1	Lying.	10	Basal
2	Sitting, doing computer work.	5	Basal
3	Standing, playing with cards.	5	Multitask
4	Standing, moving up and down a 2kg-load, metronome: 40 bits/min.	5	Multitask
5	Sitting, watching a video.	5	Basal

## RESULTS

### Selected equations

From the referred literature search, initial 124 potential approaches were identified for application within this study. After retrieving and analysis, they were reduced to 21 relevant equations from 15 authors, aimed for predicting energy requirements for resting or basal activities (De Lorenzo et al., 2001; Food, Organisation, & Committee, 1973; Harris & Benedict, 1919; Henry, 2005; Korth et al., 2007; Liu, Lu, & Chen, 1995; Livingston & Kohlstadt, 2005; Mifflin et al., 1990; Miyake et al., 2011; Müller et al., 2004; Owen et al., 1987; Owen et al., 1986; Roza & Shizgal, 1984; ten Haaf & Weijs, 2014; Wang et al., 2000; Yang et al., 2010). These equations are respectively presented in Table 3. For calculations, they were all converted for uniform results in kcal/min.

**Table 3.** Predictive equations for resting activities.

Author	Equations	
	Male	Female
<b>Harris-Benedict</b>	$66.4730 + 13.7516*w + 5.0033*h - 6.7550*a$	$655.0955 + 9.5634*w + 1.8496*h - 4.6756*a$
<b>Owen</b>	$879 + 10.2*w$	$795 + 7.18*w$
<b>Mifflin</b>	$10*w + 6.25*h - 5*a + 5$	$10*w + 6.25*h - 5*a - 161$
<b>Liu</b>	$13.88*w + 4.16*h - 3.43*a - 112.40*s + 54.34$ (for s: male=0 and female=1)	
<b>Ganpule</b>	$(0.0481*w + 0.0234*h - 0.0138*a - 0.4235)*1000/4.186$	$(0.0481*w + 0.0234*h - 0.0138*a - 0.9708)*1000/4.186$
<b>FAO/WHO/UNU (weight)</b>	$0.0640*w + 2.84$ ; $18 \leq a < 30$	$0.0615*w + 2.08$ ; $18 \leq a < 30$
	$0.0485*w + 3.67$ ; $30 \leq a < 60$	$0.0364*w + 3.47$ ; $30 \leq a < 60$
<b>FAO/WHO/UNU (weight-height)</b>	$64.4*w - 113.0*h + 3000$ ; $18 \leq a < 30$	$55.6*w + 1397.4*h + 146$ ; $18 \leq a < 30$
	$47.2*w + 66.9*h + 3769$ ; $30 \leq a < 60$	$36.4*w - 104.6*h + 3619$ ; $30 \leq a < 60$
<b>Henry</b>	$14.4*w + 313*h + 113$ ; $18 \leq a < 30$ (h in meters)	$10.4*w + 615*h - 282$ ; $18 \leq a < 30$ (h in meters)
	$11.4*w + 541*h - 137$ ; $30 \leq a < 60$ (h in meters)	$8.18*w + 502*h - 11.6$ ; $30 \leq a < 60$ (h in meters)
<b>Muller Model 1</b>	$(0.047*w + 1.009*s - 0.01452*a + 3.21)*238.85$ (for s: male=1 and female=0)	
<b>Muller Model 2</b>	$(0.05192*FFM + 0.04036*FM + 0.869*s - 0.01181*a + 2.992)*238.85$ (for s: male=1 and female=0)	
<b>Livingston</b>	$293*w^{0.4330} - 5.92*a$	$248*w^{0.4356} - 5.09*a$

Author	Equations	
	Male	Female
Korth	$41.5*w - 19.1*a + 35*h + 1107.4*s - 1731.2$ (for s: male=1 and female=0)	
De Lorenzo	$53.284*w + 20.957*h - 23.857*a + 487$	$46.322*w + 15.744*h - 16.66*a - 944$
Yang Model 1	$277 + 89*w + 600*s$ (for s: male=1 and female=0)	
Yang Model 2	$105*w - 58$	$69*w + 1335$
Wang	$24.6 * FFM + 175$	
Roza	$88.362 + 4.799*h + 13.397*w - 5.677*a$	$447.593 + 3.098*h + 9.247*w - 4.330*a$
Hhaf & Weijs	$22.771*FFM + 484.264$	

s=sex; w=weight (kg); h=height (cm); a=age (years); FFM=fat-free mass (kg); FM=fat mass (kg)

### Experimental results

Considering the differences between measured and predicted results, average outcomes revealed that the equation which better adapted to the three evaluated activities was the one proposed in Korth's study (Korth et al., 2007). Fig. 1 shows mean measured values from all participants and the estimations that most accurately approximated to the oximetry values.

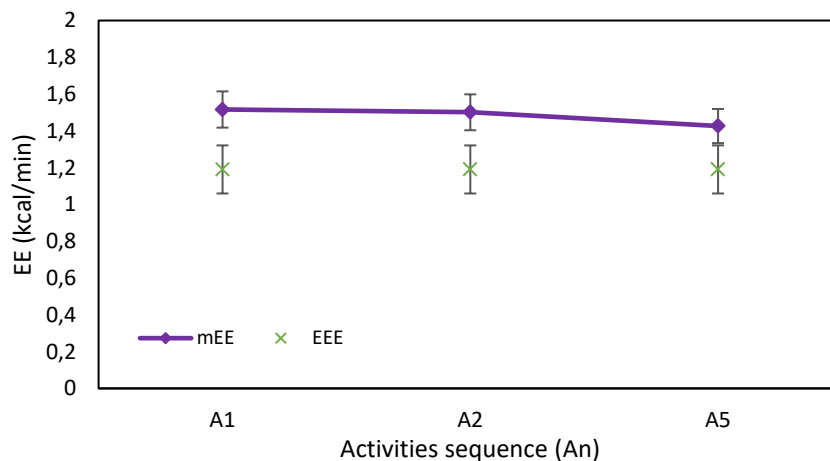


Figure 1. Measured EE (mEE) vs. Estimated EE (EEE) per activity

Figure 2 and Figure 3 present the average results for men and women, respectively. Korth's equation proved to be most accurate for males while the Haaf&Weijs' model gave better results for females.

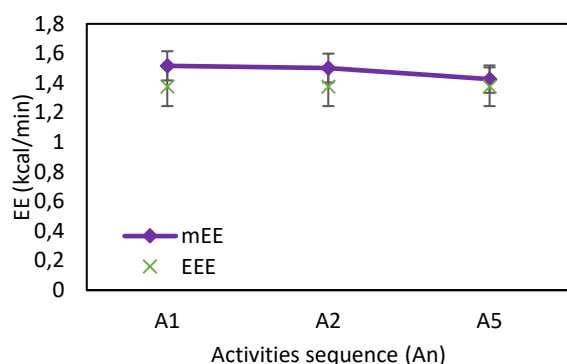


Figure 2. Measured EE (mEE) vs. Estimated EE (EEE) in males

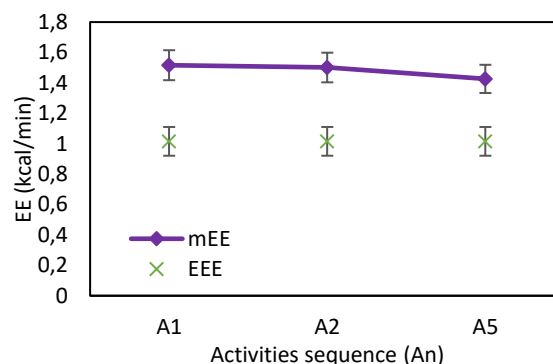


Figure 3. Measured EE (mEE) vs. Estimated EE (EEE) in females

## DISCUSSION

Through this study, a comprehensive summary of available REE equations was gathered and, their predictive power was tested within laboratory trials. As a result, it was possible to identify the equations that better estimate energy requirements when compared to measured values from a gold standard ( $K_4b^2$ ). From a general perspective, most participants evidenced Korth's equation to be the one predicting values with a better approximation to  $K_4b^2$ , followed by the Haaf&Weij's equation. Overall, better outcomes were observed with equations combining more than one anthropometric variable. Those applying only body weight for example (Food et al., 1973; Owen et al., 1987; Owen et al., 1986), evidenced the biggest differences. In fact, the best-obtained results (Korth and Haaf&Weij's) were based on a combination of various variables. Korth proposes a formula considering weight, height, sex, and age, while Haaf&Weij's model is based on fat-free mass (FFM). As FFM can be expressed by a function of age, sex, height, and body weight, it was demonstrated that compared to FFM, body weight alone was inferior as a predictor of REE and its predictive power can be substantially improved by the inclusion of height, sex and age (Korth et al., 2007). Notably, from the individual analysis, Korth's equation proved to work well for men in most cases and poorly for women. Correspondingly, Haaf&Weij's equation gave better results for females. Despite all, they both were responsible for the majority of the most accurate results. For the few cases in which different equations were identified, Korth and Haaf&Weij's equations still appeared as the second best. As Korth et al. (2007) anticipated, choosing the appropriate resting predictive equations should be based on the agreement of the study population and protocol with the characteristics of the reference population and study protocol used for generation of the equation. In that regard, it was evidenced that anthropometrics from Korth's study and only male participants from this study were comparable, which can explain why the equation worked well mostly for the male proportion of the sample. What is more, observing Figures 2 and 3, results from the male proportion of the sample demonstrate better approximations than both, the general and females' outcomes. Correspondingly, the significant differences identified on some anthropometric characteristics in females populations (age, height, and FFM) clarify the big variations between EE estimations and measurements (Fig. 3) within this group. Specifically, FFM explains 60-70% of the inter-individual variance in REEs which can justify their distance from measured values, even considering the associated error reported by the authors. In that last



respect, for this study, comparisons were made considering stated deviations from both equations and reference equipment. Korth indicates a standard estimated error of 788 kJ/day (approximately 0.13 kcal/min) while Haaf&Weijs reports a deviation of 0.57 MJ/day for females (approximately 0.095 kcal/min). On the other hand, considering the error from the K4b2, the manufacturer claims a 2% but within several validation studies, variations evidence percentages of up to 6.5% (Ross, ALDuhishy, & González-Haro, 2019). For this work, this last maximum value was applied. Despite considering the referred error limits, only the male proportion of the sample proved to provide representative predictions. Thus, future studies need to be performed within bigger samples. Finally, the associated deviations from measured values indicate more reliable results than a Level 1 (two with better accuracy than a Level 2) of the assessment approaches (for energy consumption while working) referred in the ISO standard (ISO, 2004). Estimated outcomes evidenced approximately 25, 20 and 16 % of error for activities one, two and five, respectively. As a result, the applicability of predictive equations was demonstrated but needs to be validated within bigger samples to corroborate their proximity to the ranges referred to in the standard.

### Limitations

The number of volunteers must be higher in order to support the reliability of the results and potentially reduce obtained deviations. Furthermore, the addition of more time within each designed activity would also allow a better comparison of outcomes.

### **CONCLUSIONS**

To facilitate the process of energy expenditure estimation, several equations for basal-equivalent activities were tested within a laboratory experience. Based on the obtained results, the most accurate predictions to the studied population were determined. In general, Korth (weight, height, sex and age) and Haaf&Weijs (based on FFM) equations proved to be more accurate. As a result, since body composition measurement is not always possible, the equation of Korth is advised for use in a young subjects' sample with similar overall characteristics to the sample hereby presented. As a consequence of the specificity of a REE equation, a researcher has to deal with the trade-off between internal and external validity: the more homogeneous the population, the more accurate the REE prediction but the less applicable to a heterogeneous population. Thus, future studies should be developed to test the equation within bigger samples and propose a new regression model that better adapts to the studied population.

### **References**

- De Lorenzo, A., Tagliabue, A., Andreoli, A., Testolin, G., Comelli, M., & Deurenberg, P. (2001). Measured and predicted resting metabolic rate in Italian males and females, aged 18–59 y. *European journal of clinical nutrition*, 55(3), 208.
- Food, J., Organisation, A., & Committee, W. H. O. A. H. E. (1973). Energy and protein requirements. Paper presented at the FAO Nutrition Meetings Report Series.
- Harris, J. A., & Benedict, F. G. (1919). A biometric study of basal metabolism in man: Carnegie institution of Washington.
- Henry, C. (2005). Basal metabolic rate studies in humans: measurement and development of new equations. *Public health nutrition*, 8(7a), 1133-1152.
- ISO. (2004). 8996: 2004 Ergonomics of the thermal environment—determination of metabolic rate.

- Korth, O., Bosity-Westphal, A., Zschoche, P., Glüer, C., Heller, M., & Müller, M. (2007). Influence of methods used in body composition analysis on the prediction of resting energy expenditure. *European journal of clinical nutrition*, 61(5), 582.
- Liu, H.-Y., Lu, Y.-F., & Chen, W.-J. (1995). Predictive equations for basal metabolic rate in Chinese adults: a cross-validation study. *Journal of the American Dietetic Association*, 95(12), 1403-1408.
- Livingston, E. H., & Kohlstadt, I. (2005). Simplified Resting Metabolic Rate—Predicting Formulas for Normal-Sized and Obese Individuals. *Obesity research*, 13(7), 1255-1262.
- Lucena, A. D., Guedes, J., Vaz, M. A. P., & Silva, L. B. (2018). Physiological variables in energy expenditure estimation by actigraphy: a systematic review protocol. *International Journal of Occupational and Environmental Safety*, 2(1), 59-66.
- Mifflin, M. D., St Jeor, S. T., Hill, L. A., Scott, B. J., Daugherty, S. A., & Koh, Y. O. (1990). A new predictive equation for resting energy expenditure in healthy individuals. *The American Journal of Clinical Nutrition*, 51(2), 241-247. doi:10.1093/ajcn/51.2.241
- Miyake, R., Tanaka, S., Ohkawara, K., Ishikawa-Takata, K., Hikiyama, Y., Taguri, E., . . . Tabata, I. (2011). Validity of predictive equations for basal metabolic rate in Japanese adults. *Journal of nutritional science and vitaminology*, 57(3), 224-232.
- Müller, M. J., Bosity-Westphal, A., Klaus, S., Kreyman, G., Lüthmann, P. M., Neuhäuser-Berthold, M., . . . Selberg, O. (2004). World Health Organization equations have shortcomings for predicting resting energy expenditure in persons from a modern, affluent population: generation of a new reference standard from a retrospective analysis of a German database of resting energy expenditure. *The American journal of clinical nutrition*, 80(5), 1379-1390.
- Owen, O. E., Holup, J. L., D'Alessio, D. A., Craig, E. S., Polansky, M., Smalley, K. J., . . . Mozzoli, M. A. (1987). A reappraisal of the caloric requirements of men. *The American journal of clinical nutrition*, 46(6), 875-885.
- Owen, O. E., Kavle, E., Owen, R. S., Polansky, M., Caprio, S., Mozzoli, M. A., . . . Boden, G. (1986). A reappraisal of caloric requirements in healthy women. *The American journal of clinical nutrition*, 44(1), 1-19.
- Ross, R., AlDuhishy, A., & González-Haro, C. (2019). Validation of the Cosmed K4b2 Portable Metabolic System During Running Outdoors. *Journal of strength and conditioning research*.
- Roza, A. M., & Shizgal, H. M. (1984). The Harris Benedict equation reevaluated: resting energy requirements and the body cell mass. *The American journal of clinical nutrition*, 40(1), 168-182.
- Sabounchi, N. S., Rahmandad, H., & Ammerman, A. (2013). Best-fitting prediction equations for basal metabolic rate: Informing obesity interventions in diverse populations. *International Journal of Obesity*, 37(10), 1364-1370. doi:10.1038/ijo.2012.218
- ten Haaf, T., & Weijs, P. J. (2014). Resting energy expenditure prediction in recreational athletes of 18–35 years: confirmation of Cunningham equation and an improved weight-based alternative. *PloS one*, 9(10), e108460.
- Wang, Z., Heshka, S., Gallagher, D., Boozer, C. N., Kotler, D. P., & Heymsfield, S. B. (2000). Resting energy expenditure-fat-free mass relationship: new insights provided by body composition modeling. *American Journal of Physiology-Endocrinology And Metabolism*, 279(3), E539-E545.
- Yang, X., Li, M., Mao, D., Zeng, G., Zhuo, Q., Hu, W., . . . Huang, C. (2010). Basal energy expenditure in southern Chinese healthy adults: measurement and development of a new equation. *British journal of nutrition*, 104(12), 1817-1823.

# Quantitative Risk Analysis and Consequence Modeling the Explosion of Methane Storage Tanks in a Gas Refinery

Sara Shahedi Ali Abadi<sup>1</sup>, Mojtaba Shekarestan<sup>2</sup>, Iraj Mohammad Fam<sup>3</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT (s\_shahedi@yahoo.com), <sup>2</sup>Faculty of Engineering, University of Porto, PT (mojtabataba.shekarestan@gmail.com), <sup>3</sup>Faculty of Health, Hamedan University of Medical Sciences, IR  
[https://doi.org/10.24840/978-972-752-260-6\\_0103-0109](https://doi.org/10.24840/978-972-752-260-6_0103-0109)

## Abstract

**Introduction:** The major and high quality fossil fuels (oil and gas) have been widely used in various industries such as refineries. It is even though there are very high potentials for hazards in refineries and in the methane gas process, in particular, causing human and financial losses as a result of hazards leading to accidents. This study was aimed to quantitatively analyze the explosion risk of methane gas tanks in a refinery by analyzing the risk, and modeling and evaluating the related consequences. **Materials and Methods:** Hazard analysis by PHA (Primarily Hazard analysis) was used to choose the worst-case scenario. Then, the causes of the scenario and its probability were determined by FTA (fault tree analysis) Finally, PHAST (Process Hazard Analysis Software Tool) software package was employed to model and analyze the consequences. **Results:** Based on the results concluded by the preliminary hazard analysis, the explosion of methane gas tank (V-100) was selected as the worst-case scenario at the refinery. The qualitative fault tree showed three factors including mechanical, process, and human failures contribute to gas leakage. The leakage size and weather conditions were effective on the distance of explosion overpressure. Using the consequence modeling, including the discharge, dispersion, and scenario consequence modeling, vapor cloud explosion (VCE) was considered as the major consequence of the accident. Finally, to evaluate the consequence, probit equations were used to quantify losses and the percentage of fatalities due to the methane gas leakage and explosion occurrence. The maximum number of fatalities caused by explosion was 16 persons. **Conclusions:** In conclusion, the methane gas vessel in the refinery can be considered as the main source of hazard, therefore elimination of the mechanical failures, blast proofing against the explosions, implementation of the safety rules and procedures and personal protection equipment are proposed for decreasing the probable losses and fatalities.

**Keywords:** Explosion, Gas Refinery, Consequence Modeling, Risk Analysis, Methan, FTA, PHAST, Probit.

## INTRODUCTION

The growth of energy supplies is required to meet the human needs and future developments around the world (Dan, Lee, Park, Shin, & Yoon, 2014; Mohammadfam & Zarei, 2015). By the 20th century, more attention was paid to natural gas and oil among the various sources of energy (Dan et al., 2014). A major step for gas production is processing the extracted gas in a refinery, therefore, being operational is a vital need for gas refineries. In such plants, there are chemical hazards, as well as high pressure and temperature conditions in operational units due to the existing reactors and storage tanks. Thus, in spite of all advantages of natural gas, its production, storage, transportation, and usage may result in some hazards such as explosion and fire (E.Zarei, MJ. Jafari, A.Dormohammadi, & V.Sarsangi, 2013). The hazards of natural gas can arise from high flammability and high levels of released energy in the event of explosion or fire (Mohammadfam & Zarei, 2015). Furthermore, the development of urbanization in the refinery area, the growth of these plants, and the increased number of employees can lead to increasing the frequency and severity of accidents and irreparable and hard damages. According to statistics, a lot of events and accidents related to the gas industry have happened in refineries around the world. Hence, the safety of refineries have been thoughtfully considered to avoid accidents and protect the safety of personnel, properties, and the environment (E.Zarei et al., 2013; Tong, Wu, Wang, & Wu, 2016). In recent years, various studies with diverse aims and methods have been conducted on different aspects of industrial safety particularly in process industries related to methane gas. It is obvious that in recent studies less attention has been paid to safety in natural gas refineries than that of other sectors. It is even though there are very high potentials for hazards in refineries and in the methane gas process, in particular, causing

human and financial losses as a result of hazards leading to accidents. In the few conducted studies in refineries, the main focus has been on the risk assessment and analysis, while the modeling and evaluating the consequences of accidents have been less investigated. This study was conducted in a refinery to analyze the risk of hazardous material leakage, model and evaluate the related consequences using the preliminary hazard analysis (PHA), fault tree analysis (FTA), and the Process Hazard Analysis Software Tool (PHAST). To decrease the risk of accidents in the chemical industries, it is necessary to assess the probability and the severity of their consequences. In this regard, this study was aimed to quantitatively analyze the explosion risk of methane gas tanks in a gas refinery.

## METHODOLOGY

This study was implemented based on a framework consisting of some steps proportional to the conditions of operational units. The framework included PHA technique to identify the hazard points, FTA technique for qualitative and quantitative analysis, and the PHAST software package for modeling and evaluating the hazard consequences.

### Worst case scenarios selection

In this step of the study, the scenarios with the highest severity and probability of occurrence were selected. Finally, after analyzing the results obtained from PHA worksheets, the explosion of methane gas tank (V-100) was selected as the worst-case scenario at the refinery. Operating and Atmospheric conditions related to the study are shown in Table 1 and Table 2.

**Table 1.** Operating conditions used for discharge modeling

Scenario location	Material composition	Process condition		Volume (m <sup>3</sup> )
		P (bar)	T (°C)	
High pressure methane vessel	CH <sub>4</sub>	120	45	19

**Table 2.** Atmospheric conditions corresponding to an operating duration

Atmospheric parameter	value
Wind flow velocity (m/s)	1.2- 5
Atmospheric stability class	D, F
Ambient temperature (°C)	10
Relative humidity (%)	67

### Qualitative analysis and determining the repeatability of scenario

As fault Tree Analysis (FTA) can provide much more accurate, specific, and realistic results than the database of accidents, in this study, the FTA method was used. To determine the probability of basic events, the viewpoints of experts, OREDA offshore reliability data handbook, and a study by Khosravirad were used (Khosravirad, Zarei, Mohammadfam, Shoja, & Majidi Daryani, 2016; Participants, 2002).

### Consequence Modeling of the Scenario

Consequence modeling aims to determine the increase rate of explosion shock waves in different distances and time intervals relative to the occurrence place of scenario. The

consequence modeling includes the discharge modeling, dispersion modeling and scenario consequence modeling.

#### Consequence Modeling

Vapor cloud explosion (VCE) was considered as the major repercussion of the accident. The best-known model to estimate the consequences, TNO Multi-Energy model, was used in this study (Grossel, 2001). The selected worst-case scenario in three leakage sizes of 50, 100, and 250 mm, and in the complete rupture of the tank were modeled using the most appropriate software for modeling Process Hazard Analysis Software Tool (PHASt) 7.11. (Al-shanini, Ahmad, & Khan, 2014; E.Zarei et al., 2013; Gant, Narasimhamurthy, Skjold, Jamois, & Proust, 2014; M. J. Jafari, Zarei, & Badri, 2012; Mohammadfam & Zarei, 2015; Parvini & Kordrostami, 2014; Tong et al., 2016; Zarei, Jafari, & Badri, 2013).

#### Consequence Evaluation

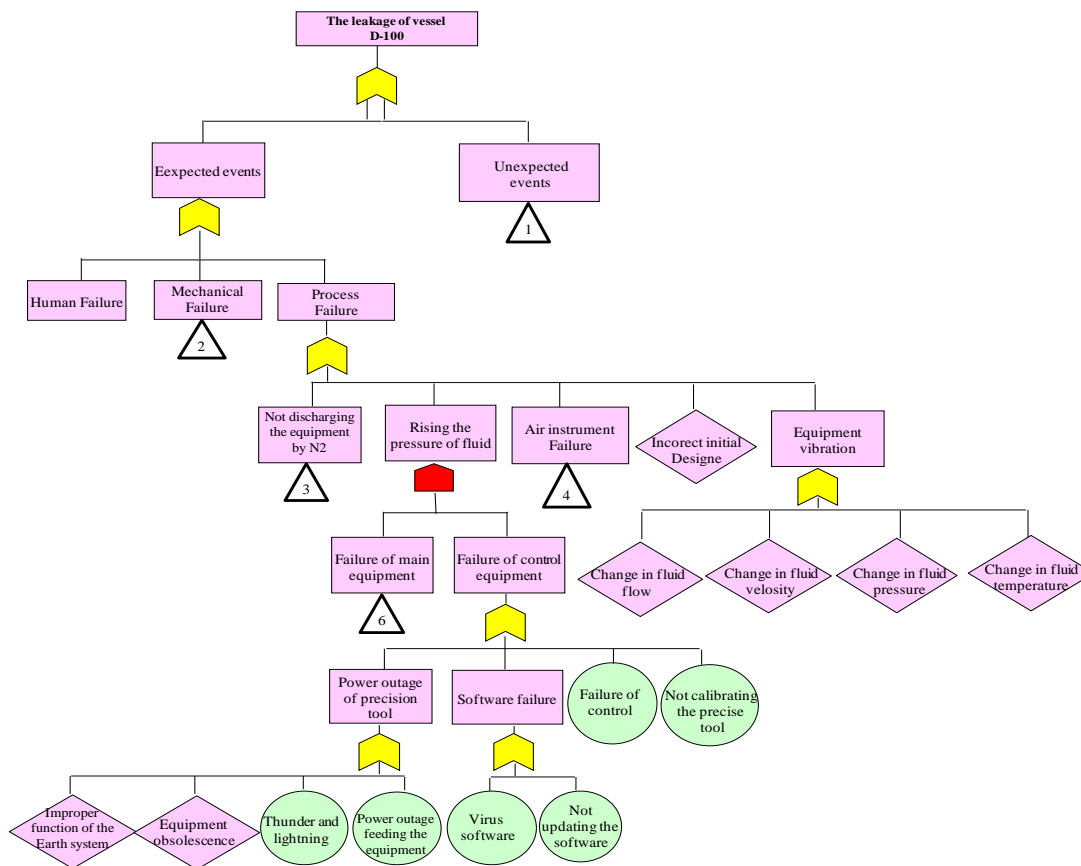
Finally, after consequence modeling, its evaluation was taken into account. At first, damages and losses caused as a result of scenario (VCE) were calculated. In this study, consequence evaluation aimed to determine the percentage of fatalities (Mohammadfam & Zarei, 2015). Valid probit equations were used to quantify the percentage of the population who were exposed to vapor cloud explosion due to methane gas leakage from tank V-100 (M. Jafari, Zarei, & Dormohammadi, 2013; Lees, 2012).

### **RESULT AND DISCUSSION**

After reviewing the existing hazard checklists and hazards analyses (previously conducted), methane gas pressure vessel (V-100) at the pressure of 120 bar and temperature of 45°C was introduced as the main source of hazard and a basis for extracting the selected scenario. Surveying the process and accidents statistics, as well as site inspection, were led to selecting the explosion of this vessel as an important scenario. The obtained results from analyzing the causes of scenario occurrence using FTA method are as follow: The qualitative fault tree showed that three factors including mechanical, process and human failures contribute to gas leakage from tank V-100. Because of the large size of the drawn fault tree for gas leakage, a part of it has been indicated in Figure 1. After qualitative fault tree analysis, the probability of basic event occurrence was calculated (Table 3) (Khosravirad et al., 2016; Participants, 2002). The results proved that mechanical failures with the failure probability of 0.0899 were the main cause for the occurrence of the selected scenario. The second and third orders were devoted to the process and human failures with failure probabilities of 0.0568 and 0.0439, respectively. The probability of accident occurrence in a year was estimated to be 0.19. In order to model the consequence of the scenario, environmental and operational conditions were studied. Vapor cloud explosion (VCE) was determined as the main hazard related to methane gas leakage from the tank. Figure 2 illustrates the results obtained from modeling the vapor cloud explosion. The maximum area affected by the VCE was related to rupture of 250 mm. In addition, the safe distances from the accident were 633 meters for category 5D and 613 meters for category 1.2F. The results showed that the weather condition and the amount of overpressure had considerable effects on the contours of the worst-case explosion overpressure in all sizes of ruptures (Figures 3 and Figure 4).

**Table 3.** Failure probabilities and failure rates obtained for three main contributors to scenario occurrence

Contributors to gas leakage	No.	Basic event	Failure probability	Total failure probability	Failure rate
Process failure	1	Software failure	0.0014	0.0568	0.06
	2	Valve failure of precise tools	0.001		
	3	Equipment obsolescence	0.0026		
	4	Improper function of the Earth system	0.0018		
	n	--	--		
Mechanical failure	1	Welding failure	0.002	0.0899	0.09
	2	Destruction of the anti-corrosion layer	0.008		
	3	Abrasion	0.005		
	4	Valves obsolescence	0.007		
	n	--	--		
Human failure	1	Stress	0.039	0.0439	0.045
	2	Shift work	0.04		
	3	Fatigue	0.075		
	4	Lack of skills and experience	0.014		
	n	--	--		
<b>Total</b>				<b>0.1906</b>	<b>0.211</b>



**Figure 1.** Fault Tree Analysis drawn for V-100

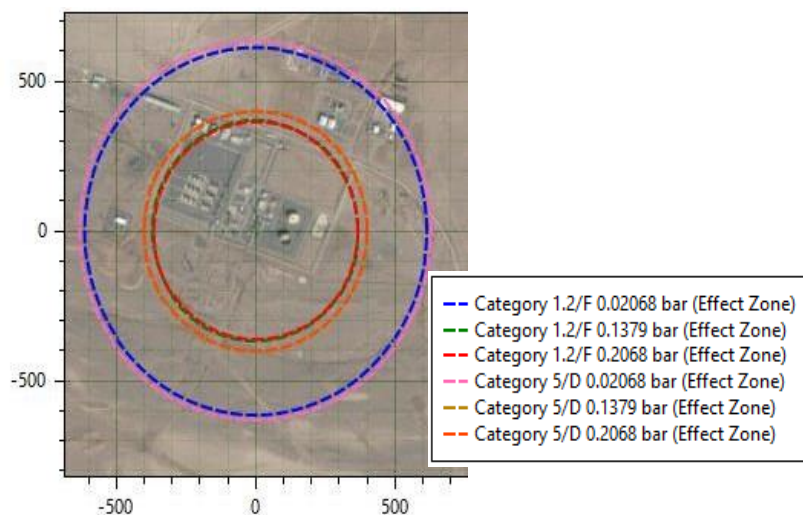


Figure 2. Late explosion worst case at 250mm leakage

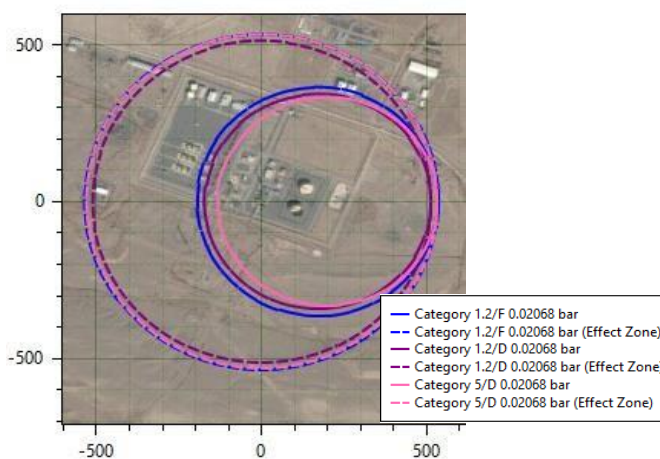


Figure 3. Late explosion worst case at 100mm leakage

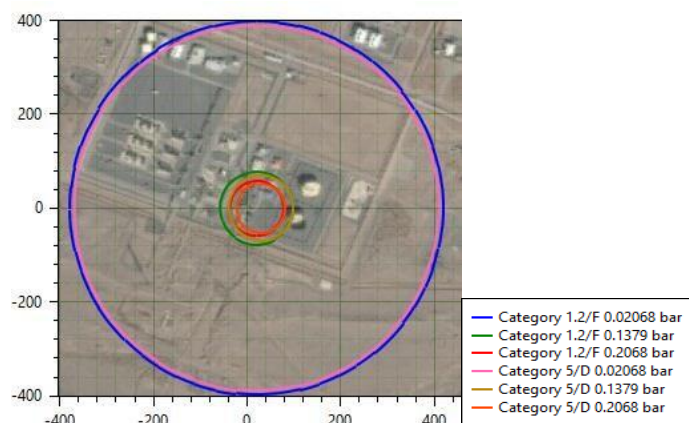


Figure 4. Late explosion worst case at catastrophic rupture

Table 4 shows the affected distances in different criteria of explosion overpressure considering the leakage sizes in three weather conditions. In all leakage sizes, except for catastrophic rupture in overpressure of 0.02 bar, increasing the wind flow velocity had a direct impact on affected distance. However, the atmospheric stability in all scenarios, except for the leakage sizes of 50

and 100 mm in overpressure of 0.02 bar, had no considerable impact on mentioned distance. In size of 50 mm, the overpressure distance increased with increasing the atmospheric stability (category F).

**Table 4.** The affected distances (m) in various criteria of the explosion

Overpressure (bar)	0.02			0.1			0.2		
	Weather conditions								
Leakage size (mm)	1.2	1.2	5 D	1.2	1.2	5 D	1.2	1.2	5 D
	F	D		F	D		F	D	
50	250	232	239	146	133	143	139	128	137
100	535	512	532	262	262	295	257	257	292
250	613	613	633	369	369	401	366	366	401
Catastrophic rupture	419	419	409	97	97	99	78	78	82

The results indicate that the rupture of 250 mm with an overpressure of 0.2 bar will cause the maximum number of fatalities (16 persons). The incurred losses were obtained using the probit equations (Table 5).

**Table 5.** The number of fatalities in different scenarios based on probit equations

Scenario number	Leakage size (mm)	Effect area (m <sup>2</sup> )	Probit value	Fatality percent	Fatality number
1	50	58934.66	2.9	5	2
2	100	267728.96	2.9	5	9
3	250	504915.14	2.9	5	16
4	Catastrophic rupture	21113.36	2.9	5	1

## CONCLUSIONS

In this study, quantitative risk analysis was conducted for the explosion of methane gas tank in a gas refinery. The fatality rate caused by (VCE) was considered as the main consequence of the accident. The study did not examine the probability of fire occurrence. According to results of the preliminary hazard analysis, methane gas tank (V-100) with an operating pressure of 120 bar and a temperature of 45°C was introduced as the main center of hazard. In this regard, the explosion of tank was surveyed in three sizes of leakage and in the state of catastrophic rupture. Following the analysis of causes of scenario occurrence, the mechanical failures with a failure probability of 0.0899 were estimated to be the most contributing factor for the scenario to happen. Results showed that the leakage size had a significant impact on areas affected by the explosion overpressure so that the maximum and minimum areas were devoted to leakage size of 250 mm and 50 mm, respectively (Table 4). In all leakage sizes, the blast radius can reach to the fire station and control room. Figure 4 illustrates the most dangerous state of vapor cloud explosion caused by the leakage size of 250 mm. By this leakage size, the office building and resorts for refinery workers fall within the scope of the risk. Analyzing the weather conditions showed that in all leakage sizes, except for catastrophic rupture in overpressure of 0.02 bar, increasing the wind flow velocity had a direct impact on blast radius. However, the atmospheric stability in all scenarios, except for the leakage sizes of 50 and 100 mm in overpressure of 0.02 bar, had no remarkable impact on these sizes. In the leakage size of 50 mm, increasing the



atmospheric stability (category F) led to increase of the blast radius (Table 4). Wind speed helps methane dispersion to greater distances, therefore a larger area is affected by the explosion occurrence. The maximum number of fatalities (16 persons) caused by explosion occurrence was obtained for the leakage size of 250 mm in the category of 5D. Considering the policy for expanding the studied refinery and attracting more workforce as well as the development of urbanization in future, accident occurrence can cause more losses and fatalities than that of the present study. In conclusion, the application of appropriate devices for detecting the leakages, elimination of mechanical failures, and using the suitable and practical measures to decrease the probability and severity of potential accidents are proposed for decreasing the probable losses and fatalities.

## References

- Al-shanini, A., Ahmad, A., & Khan, F. (2014). Accident modelling and analysis in process industries. *Journal of Loss Prevention in the Process Industries*, 32, 319-334. doi:<http://dx.doi.org/10.1016/j.jlp.2014.09.016>
- Dan, S., Lee, C. J., Park, J., Shin, D., & Yoon, E. S. (2014). Quantitative risk analysis of fire and explosion on the top-side LNG-liquefaction process of LNG-FPSO. *Process Safety and Environmental Protection*, 92(5), 430-441. doi:<http://dx.doi.org/10.1016/j.psep.2014.04.011>
- E.Zarei, M.J. Jafari, A.Dormohammadi, & V.Sarsangi. (2013). The Role of Modeling and Consequence Evaluation in Improving Safety Level of Industrial Hazardous Installations: A Case Study: Hydrogen Production Unit. *Iran Occupational Health Journal*, 10(6), 54-69.
- Gant, S. E., Narasimhamurthy, V. D., Skjold, T., Jamois, D., & Proust, C. (2014). Evaluation of multi- phase atmospheric dispersion models for application to Carbon Capture and Storage. *Journal of Loss Prevention in the Process Industries*, 32, 286-298. doi:<http://dx.doi.org/10.1016/j.jlp.2014.09.014>
- Grossel, S. S. (2001). *Guidelines for Chemical Process Quantitative Risk Analysis*; By Center for Chemical Process Safety; American Institute of Chemical Engineers, New York, NY, 2000, pp. 750. In: Elsevier.
- Jafari, M., Zarei, E., & Dormohammadi, A. (2013). Presentation of a method for consequence modeling and quantitative risk assessment of fire and explosion in process industry (Case study: Hydrogen Production Process). *Journal of Health and Safety at Work*, 3(1), 55-68.
- Jafari, M. J., Zarei, E., & Badri, N. (2012). The quantitative risk assessment of a hydrogen generation unit. *International Journal of Hydrogen Energy*, 37(24), 19241-19249.
- Khosravirad, F., Zarei, E., Mohammadfam, I., Shoja, E., & Majidi Daryani, M. (2016). Explosion risk analysis on Town Border Stations (TBS) of natural gas using Failure Mode & Effect Analysis (FMEA (and Fault Tree Analyses (FTA (methods. *Iran Occupational Health Journal*, 12(6), 16- 27.
- Lees, F. (2012). *Lees' Loss prevention in the process industries: Hazard identification, assessment and control*: Butterworth-Heinemann.
- Mohammadfam, I., & Zarei, E. (2015). Safety risk modeling and major accidents analysis of hydrogen and natural gas releases: A comprehensive risk analysis framework. *International Journal of Hydrogen Energy*, 40(39), 13653-13663. doi:<http://dx.doi.org/10.1016/j.ijhydene.2015.07.117>
- Participants, O. (2002). *OREDA Offshore Reliability Data Handbook*. In: DNV, PO Box.
- Parvini, M., & Kordrostami, A. (2014). Consequence modeling of explosion at Azad-Shahr CNG refueling station. *Journal of Loss Prevention in the Process Industries*, 30, 47-54. doi:<http://dx.doi.org/10.1016/j.jlp.2014.04.007>
- Tong, S.-j., Wu, Z.-z., Wang, R.-j., & Wu, H. (2016). Fire Risk Study of Long-distance Oil and Gas Pipeline Based on QRA. *Procedia Engineering*, 135, 368-374. doi:<http://dx.doi.org/10.1016/j.proeng.2016.01.144>
- Zarei, E., Jafari, M. J., & Badri, N. (2013). Risk assessment of vapor cloud explosions in a hydrogen production facility with consequence modeling. *Journal of research in health sciences*, 13(2), 181-187.

# The sound aesthetic of servicescape: influence in the aesthetic experience of employees

Humberto Costa<sup>1</sup>, Trajano F. B. X. Silva<sup>2</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT, ([humbertocosta@gmail.com](mailto:humbertocosta@gmail.com)) ORCID 0000-0003-0329-9004, <sup>2</sup>Faculty of Engineering, University of Porto, PT, ([up201802228@fe.up.pt](mailto:up201802228@fe.up.pt)) ORCID: 0000-0001-7168-4161  
[https://doi.org/10.24840/978-972-752-260-6\\_0110-0114](https://doi.org/10.24840/978-972-752-260-6_0110-0114)

## Abstract

**Introduction:** This research deals with the influence of the soundscape of the servicescape along to collaborators, according to the service design perspective. It is understood that Service Design (SD) covers the design of the entire service experience, as well as the design of the process and the strategies for delivering it. Some elements that are included in this process include the provider, developers, servicescape, products, clients, etc. The central point of the SD is to understand the value and nature of relationships between people and people, between people and things, between people and organizations, and between organizations of various kinds. In the scope of SD, the Aesthetic dimension assumes a higher level of complexity, since the relational aspects between human beings (employees and clients) are added, elements that often determine the quality of the experience of service as a whole. In order for the customer to receive an excellent service, it is essential to pay attention to the condition of the employees who provide the service. In this respect, an aesthetic approach has the potential to diagnose and enable innovative solutions to be better explored. The problem was questioned: how does sound aesthetics influence the aesthetic experience of collaborators in servicescape? The objective was to demonstrate how sound aesthetics influence the aesthetic experience of employees in a servicescape. **Methodology:** To answer the research question, a bibliographic review was carried out, and a survey was undertaken in a shopping mall in the city of Curitiba / Brazil. The RPE-Audição tool was used to collect the data. The survey counted on the participation of employees who work in the servicescape of the company that provides the service. **Results and Discussion:** The results showed that the soundscape of servicescape influences the creation and maintenance of the mood state and can directly impact the health of the employees. The soundscape of the analyzed servicescape evokes positive emotions in the collaborators. In a servicescape focused on hedonic consumption, it is essential that positive emotions are evoked and reinforced, as they can create or reinforce positive moods as well. Such a scenario can bring better working conditions to employees, impact on the quality of life, health, potentiate consumption and interfere in the creation of a positive image about the establishment. **Conclusions:** As a suggestion for future work, it is recommended to conduct research involving other hedonic service environments in order to deepen the knowledge about the influence of the sound landscape on the aesthetic experience of the collaborators.

**Keywords:** Sound aesthetics, Aesthetic Experience, Servicescape, Service Design, Sound Landscape.

## INTRODUCTION

The services sector generates the largest share of Gross Domestic Product (GDP) of the world's largest economies (Costa, 2017). The services have required the generation of specific knowledge in the field of Design (Mager, 2004) and there is also the collaborators' conditions. Aesthetics permeates all human activity, and any phenomenon has the potential to evoke aesthetic responses (Hekkert & Leder, 2008). The importance of the study of Aesthetics is greater in sectors where the aesthetic experience of people impacts on their satisfaction with the service received (Costa, 2017). This is the case of services that are provided, for example, by shopping malls. In order for the customer to receive an excellent service, it is essential to pay attention to the condition of the employees who provide the service. The question that guided this research was: How does sound aesthetics influence the aesthetic experience of employees in a given servicescape? The objective was to demonstrate how sound aesthetics influence the aesthetic experience of employees in a particular servicescape. Services refer to a provision of something that someone performs for the utility, satisfaction, or support of another person's activity (Pacenti, 2006). The service offering is based on the provision of these actions and experiences and have the purpose of delivering the benefits to someone. The value of services to people is always a combination of functional elements and emotional elements. Because it

belongs to the domain of sense construction, services can be linked to Design (Freire, 2011). It is understood that Service Design (SD) covers the design of the entire service experience, as well as the design of the process and the strategies for delivering it (Costa, 2017). Some elements that are included in this process include the provider, developers, servicescape, products, costumers, etc. The central point of the SD is to understand the value and nature of relationships between people and people, between people and things, between people and organizations, and between organizations of different kinds (Costa, 2017). According to the Greek sense, Aesthetics denotes sensation, feeling, esthesis (Rosenfield, 2009). It is Aesthetics's task to analyze the complex of human emotions and feelings by investigating "(...) their integration into the physical and mental activities of man, focusing on the productions (artistic or otherwise) of sensibility, in order to determine their relations with knowledge, reason and ethics "(Rosenfield, 2009, p.7). However, for the purposes of SD, Aesthetics must be approached by a broader meaning, that is, as an integrative experience of sensory, behavioral and reflexive perception experienced by an individual. This means that Aesthetics involves a type of human experience that begins with the sensory perception of a phenomenon (sensory level), which transforms the body landscape (behavioral level) and culminates in meaning about all the experience experienced (reflective level) (Costa, 2017). In the scope of SD, the Aesthetic dimension assumes a higher level of complexity, since the relational aspects between human beings (employees and clients) are added, elements that often determine the quality of the experience of service as a whole. One of the components of the spectrum of shades of the human sensory system consists of sounds (Schafer, 2011). Human beings use sounds not only to communicate but also to interpret and express their aesthetic perception in relation to the world around them (Schafer, 2011). Sounds are able to influence affective aspects, evoking emotions and feelings (Ackerman, 1992). Sounds have the potential to induce the listener to make decisions or influence their behavior. The diversity of sounds present in a given environment forms a "sound landscape" (Schafer, 2011). What characterizes the composition of a particular sound landscape is the presence of environmental sounds in recognizable contexts (Truax, 1996). Among the possible and often present sounds along the journey through the service is the music. Physical evidence constitutes the service environment (the servicescape). This is where the service is provided and where users and collaborators interact (Zeithaml et al., 2014). Included in the servicescape concept are all exterior attributes such as signage, parking, and landscaping, etc. As for the interior attributes, these are composed by space layout, equipment, developers, decoration, sounds, courtesy, care, empathy, etc. In relation to human behaviors in servicescape, it is known that the human being is influenced by the physical facilities. In these cases, people respond in two ways: approach and avoidance (Bitner, 1992). Approach behaviors are those related to the desire to stay, to explore, to return to the establishment, etc. On the other hand, avoidance behaviors are the opposite. The elements perceived in the service environment have the potential to induce aesthetic responses, which can influence behaviors. The qualities of the environments are of two dimensions: pleasure / displeasure and degree of enthusiasm (Bitner, 1992). Stimulating environments are viewed positively, unless enthusiasm is combined with something unpleasant, such as excessive noise, which may be avoided by some people (Zeithaml et al., 2014).

## METHODOLOGY

This research presents a qualitative and exploratory approach (Gray, 2012). As for the procedures, the bibliographic review was used and a survey was carried out with the purpose of raising information directly with a group of interest, regarding the data that one wanted to

obtain. First, a Assistamatic Bibliographic Review, RBA, (Creswell & Clark, 2013; Webster & Watson, 2002) on the themes of service design, aesthetics, aesthetic experience, services aesthetics, servicescape, sound aesthetics and sound landscape to allow greater understanding of the main terms and authors. As an initial source for the RBA, a search was made for articles published between 2010 and 2017 in the Web of Science and Ebsco Host databases, with the purpose of analyzing the density and the evolution of the research on the themes pertinent to this work. The search strings adopted were: "service design"; "Aesthetics"; "Aesthetic experience"; "Servicescape"; "Sound aesthetics" and "sound landscape". Survey research is a useful procedure in exploratory research, in which data are sought on the opinions and characteristics of a particular group of people (Gray, 2012). For the collection of data, the "Wheel of Aesthetic Perception - Audition", RPE-Audição (Costa, 2017) was used and the guidelines for the application of the instruments and for the analysis of the data were followed. The survey was conducted in the premises of Shopping Curitiba and the target audience were employees who worked in the mall. Respondents were chosen randomly, regardless of gender.

## DATA ANALYSIS AND INTERPRETATION OF RESULTS

On May 6, 2017, a survey was carried out in the premises of Shopping Curitiba, with the application of the "Wheel of Aesthetic Perception - Audition", with the purpose of collecting data about the visceral aesthetic perception evoked by the sound landscape in the collaborators. Two interviewers approached 25 employees who were distributed throughout the four floors of the establishment. It was observed that in the services of Shopping Curitiba, there are initiatives to create a "sound landscape" with the purpose of awakening and reinforcing positive moods in people, with direct contributions in their journey through the service. In general, it can be said that the sound landscape of the analyzed service environment is, from the auditory point of view, not very noisy. Table 1 shows the frequency and intensity of the emotions that are evoked in the employees from the sound landscape present in the analyzed servicescape. The table also shows the frequency and intensity with which each of the emotions is expected in the same servicescape. According to Table 1, it is noted that there is a predominance of positive emotions evoked in the collaborators. The aesthetic experience of the collaborators, in the midst of 10 most experienced emotions is based on eight positive emotions, which have high gradations (4, 5 or 6). On average, 23% of the respondents said they experienced emotions such as tranquility, Enthusiastic, happiness, fun and serenity in high gradations (4, 5 or 6). This points to a positive aesthetic experience. In a service environment focused on hedonic consumption, it is crucial that positive emotions are evoked. Positive emotions are fundamental to the creation and / or reinforcement of positive mood states. Creating and reinforcing positive moods provides a positive experience for people as well. This will contribute to a better service delivery by the employees, which has the potential to contribute to the construction of a positive image about the establishment with the customers. Moreover, it is inferred that positive moods have the potential to lead the user to consume, which would be very interesting for the establishment. In a city with several establishments focused on hedonic consumption, it is inferred that those who provide a better experience to users will be those with higher possibility of attracting even more consumers.

**Table 1.** Gradation of felt and expected emotions in servicescape Shopping Curitiba, according to the aesthetic perception evoked by hearing

Emotion (Hearing)	Gradation Felt	Expected Graduation	Indicated Degree						
			0	1	2	3	4	5	6
Happy	196	244	109	0	1	5	9	13	13
Excited	79	148	133	1	0	0	5	8	3
Enthusiastic	209	170	105	1	1	2	16	14	11
Serene	104	126	127	3	1	0	3	9	7
Fun	117	181	123	0	3	2	11	5	6
Tranquility	284	281	88	1	3	3	22	18	15
Admired	38	82	140	1	2	1	3	0	3
Affectionate	53	22	139	0	0	1	4	2	4
Stimulated	74	71	134	0	0	4	2	6	4
Inspired	77	143	133	0	1	1	5	8	2
Meditative	27	12	142	1	0	3	3	1	0
Melancholic	25	3	142	1	1	3	2	1	0
Nervous	53	1	135	3	2	2	2	4	2
Sentimental	32	31	142	1	0	1	4	0	2
Affected	6	3	146	2	2	0	0	0	0
Impatient	81	4	127	1	3	8	8	0	3
Nostalgic	40	45	140	0	2	2	2	2	2
Horrified	8	1	145	2	3	0	0	0	0
Saddened	4	1	147	2	1	0	0	0	0
Tense	76	5	131	3	1	0	7	5	3

On the other hand, it can be observed in Table 1 that negative emotions were also evoked in the collaborators by the soundscape of the servicescape analyzed. Emotions like impatience and tension were the most experienced. When it comes to collaborators, the presence of such emotions is worrying. Based on the servicescape analyzed, negative emotions should be at a level far below what was found. This assertion stems from an inference that a negative aesthetic panorama contributes to the generation / reinforcement of negative mood states as well. People with negative moods tend to retract and avoid any kind of approach, impacting the quality of the service provided. When it comes to consumption, such behavior is not desired. It was possible to verify that the respondents, although they had a positive experience, they wish that such experience is even more positive. For example, in Table 1, it can be seen that the collaborators want the experience evoked by the sound landscape to be even more calm, happy, fun, lively and serene. On the other hand, they want the negative aesthetic panorama to be minimized. For example, they want to feel less impatience, tension, nervousness, melancholy, etc. It was possible to verify that the respondents, although they had a positive experience, they wish that such experience is even more positive. For example, in Table 1, it can be seen that the collaborators want the experience evoked by the sound landscape to be even more calm, happy, fun, lively and serene. On the other hand, they want the negative aesthetic panorama to be minimized. For example, they want to feel less impatience, tension, nervousness, melancholy, etc.

## FINAL CONSIDERATIONS

It was found that the soundscape of a servicescape influences the aesthetic experience of the collaborators. In the case of auditory aesthetic perception, the non-tangible elements that make up the sound landscape are responsible for evoking emotions and feelings that can create or reinforce positive or negative mood states. The soundscape of the analyzed servicescape evokes positive emotions in the collaborators. In a servicescape focused on hedonic consumption, it is

important that positive emotions are evoked and reinforced, as they can create or reinforce positive moods as well. Such a scenario can bring better working conditions to employees, impact on the quality of life, health, potentiate consumption and interfere in the creation of a positive image about the establishment. The survey also found that the soundscape of servicescape evokes negative emotions, but in the case analyzed, in low proportions. Such a scenario is worrisome since a negative aesthetic panorama contributes to the generation or reinforcement of negative mood states. From this perspective, both employees and users tend to retract and avoid any kind of approach. When it comes to consumption, such behavior is not desired. The research also showed that employees, although they have experienced a positive aesthetic experience, expect it to be even more positive and that aesthetically negative emotions are drastically minimized. Based on this research and from the point of view of SD, it is suggested that the administration of Shopping Curitiba deepen the knowledge about employees and, based on these data, develop aesthetic guidelines to guide future solutions to improve their aesthetic experience. Another suggestion would be the involvement of employees and users in the creation of solutions to improve the aesthetic experience experienced in servicescape. Knowing the desires of employees and service users, it requires understanding their individual experiences with the service, as well as the broader context of their particularities. By knowing and understanding culture, habits, motivations and social context, as well as engaging them deeply in the exploration and definition of service improvement solutions, there is a greater possibility of creating services with high added value that will hardly be copied by the competition. As a suggestion for future work, it is recommended to carry out research involving other service environments in order to deepen the knowledge about the possible influences of the sound landscape on the aesthetic experience of the collaborators who provide the service.

## References

- Ackerman, D. (1992). *Uma História Natural dos Sentidos*. São Paulo: Bertrand.
- Bitner, M. J. (1992). Servicescapes: The Impact of Physical Surroundings on Customers and Employees. *Journal of Marketing*, 56(2), 57–71. <https://doi.org/10.1177/002224299205600205>
- Costa, H. (2017). *Design para Serviços e Consistência Estética: proposição de um protocolo de avaliação estética em serviços*. Universidade Federal do Paraná.
- Creswell, J. W., & Clark, V. L. P. (2013). *Pesquisa de Métodos* (2nd ed.). Porto Alegre: Penso.
- Freire, K. de M. (2011). *Design de Serviços, Comunicação e Inovação Social*. Pontifícia Universidade Católica do Rio de Janeiro.
- Gray, D. E. (2012). *Pesquisa no Mundo Real* (2nd ed.). Porto Alegre: Penso.
- Hekkert, P., & Leder, H. (2008). Product aesthetics. In H. N. J. Schifferstein & P. Hekkert (Eds.), *Product experience* (pp. 259–285). San Diego: Elsevier.
- Mager, B. (2004). *Service Design: A Review*. Köln: Köln Internat. School of Design.
- Pacanti, E. (2006). Design dei servizi. In *Design multiverso: appunti di fenomenologia del design* (p. 252). Milano: POLI.design.
- Rosenfield, K. H. (2009). *Estética*. Rio de Janeiro: Jorge Zahar.
- Schafer, M. R. (2011). *O Ouvido Pensante*. São Paulo: Ed. UNESP.
- Truax, B. (1996). Soundscape, Acoustic Communication and Environmental Sound Composition. *Contemporary Music Review*, 15(1–2), 49–65. <https://doi.org/10.1080/07494469608629688>
- Webster, J., & Watson, R. T. (2002). Analyzing the Past To Prepare R the Future : Writing a. *MIS Quarterley*, 26(2), xiii–xxiii. Retrieved from <https://www.jstor.org/stable/4132319>
- Zeithaml, V. A., Bitner, M. J., & Gremler, D. D. (2014). *Marketing de serviços : a empresa com foco no cliente* (6th ed.). Porto Alegre: Bookman.

# Geographic information Systems enforced to Occupational Health and Safety Practices: A short literature review

Carolina Garreto<sup>1</sup>, J. Duarte<sup>2</sup>, Jacqueline Castelo Branco<sup>3</sup>, J. C. Guedes<sup>4</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT ([carolgarreto@gmail.com](mailto:carolgarreto@gmail.com)) ORCID 0000-0001-7138-7714, <sup>2</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([jasduarte@fe.up.pt](mailto:jasduarte@fe.up.pt)) ORCID 0000-0002-5856-5317, <sup>3</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([jcb@fe.up.pt](mailto:jcb@fe.up.pt)) ORCID 0000-0002-9254-4384, <sup>4</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([jccg@fe.up.pt](mailto:jccg@fe.up.pt)) ORCID 0000-0003-2367-2187  
[https://doi.org/10.24840/978-972-752-260-6\\_0115-0118](https://doi.org/10.24840/978-972-752-260-6_0115-0118)

## Abstract

**Introduction:** Risk assessment methods are commonly used in health and safety and require rapid response tools that allow an analysis of multiple scenarios in order to reduce the loss of life, environmental and materials damages. This work is a systematic review of the available literature of Geographic Information Systems (GIS), addressing issues related to the occupational sciences of Health and Safety and/or Emergency. **Methodology:** The method used for the review was based on the PRISMA-Statement. It was developed through 4 databases (Web of Science, Scopus, Springer Link, and Science Direct). The keywords used followed the logic (Occupational OR work) AND (hygiene OR health OR safety) AND (GIS). The applied databases filters were: document type limited to Article (research) and Article in the press, Journals source, and English and Portuguese languages. **Results:** It was identified a total of 667 items, 21 of which were selected for full-text reading. As a result, five articles were selected, and the other two were identified through their reference screening. The articles comprise the years 2009 to 2017, with authors of 9 nationalities and the use of monitoring being the most present method. ArcGIS (ESRI) software was the most frequently used. Information on the risk management methods, and the GIS as a platform, were obtained in mining, construction, industry, mainly, and addressed security issues (one article), emergency (two articles) and occupational hygiene (four articles).

**Discussion:** The results of the identified articles helped on issues such as decision making, escape routes, gas concentration information records, dust and fumes, temperature monitoring, humidity, identifying areas with exposure to ionizing radiation, noise, spots identification diseases and visualization of medical complaints conditions for the workplace. It also identified the evolution of the use of GIS information platform with other technologies allowing expansion of new types of evaluation. **Conclusions:** The developed search identified addressing issues in the areas of analysis and management of risks and emergencies, even those that are not exactly worked in safety and occupational hygiene, although it can be seen that the use of the experience is feasible, information and existing approaches to develop the concept of an integrated risk analysis and dynamics within the GIS.

**Keywords:** Geographic information system, Occupational hazards, Risk management, Emergencies.

## INTRODUCTION

Risk assessment methods are commonly used in occupational health and safety to reduce accidents, risk mitigation, and prevention of diseases. The use of tools with faster and more functional responses may be essential to prevent accidents and reduce occupational diseases, so the usage of this technology in favor of this proposal can reduce costs and save lives (Delaunay et al., 2015). "A geographic information system (GIS) is a framework for gathering, managing, and analyzing data. It analyzes the spatial location and organizes layers of information into visualizations. GIS reveals deeper insights into data, such as patterns, relationships, and situations—helping users make smarter decisions." (ESRI, 2019). Thus, the GIS showed the use of characteristics relevant to what is sought by integrating data, overlay information and view responses in different contexts. It was used the safety classification for articles dealing with accidents and hygiene for those who talk about the exposure to environmental risks and health. The objective was to find evidence about the possible advantages of GIS-based techniques to support occupational safety and health (OSH) practices and support future work.

## METHODOLOGY

The description of this systematic review was made based on the guideline Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA Statement) (Moher et al., 2009). It began with the definition of the relevant keywords, used following the logic: (occupational OR work) AND (hygiene OR health OR safety) AND (GIS). The review was conducted mainly in four databases: Scopus, Web of Science, Springer link and Science Direct. The first research step was carried out in order to find more keywords and to recognize the scale of the issue. Screening procedures were based on selecting the titles dealing with the occupational context (e.g. industrial application, involving employees or bring the relationship to work). Moreover, as exclusion criteria were used: type of document (Article - research and Article in press), type of source (only Journals) and English and Portuguese languages. After the first selection and reading of articles, their references were reviewed to find the same context articles.

## RESULTS

Searches resulted in 667 articles identified through databases. After selecting the relevant articles with the use of filters, 21 studies remain, fulfilling the criteria "On Topic". When performing screening, remained five articles developing topics related to occupational health and safety, and emergency context. After this selection, articles were separated according to the OSH goal areas (hygiene, safety, and emergency). The references of the included articles were analyzed and were added to this study two more articles that fulfill the criteria. The summary of the selected studies is in Table 1. These articles cover the period from 2009 to 2017, show authors and their research in nine nationalities, especially China with two items, and monitoring as the most frequent method. All items use GIS in combination with a range of different software, including several programming languages, Office software, databases and GIS complementary packages. Occupational activities that enable user interaction make use of Web GIS interface. Most of them use the ArcGIS (ESRI) software. As for the development area related to OHS, four can be classified into occupational hygiene, two in the emergency part and one in the safety area. Four articles were developed in the mining area, but despite the quantitative relevance it was found research has been found in other types of significant industries.

## DISCUSSION

With the collection of information on the use of risk management methods together with georeferencing platform (GIS) in several areas (mining, construction, industry) and the approach to various types of risks (physical, chemical, biological, accidents), It is possible to verify the real possibility of using the platform in occupational safety and emergency. Also, occupational hygiene area is covered with the methods of monitoring the conditions and monitoring of healthcare data (such as monitoring the evolution of the contamination, disease statistics, or similar). In the safety area, Manase et al. (2011) describe the points for GIS approach OSH in the context of construction in its various phases of work. The authors use ArcGIS together with Excel and Access, developing an information system that captures, analyzes and presents information to assist decision making in the context of accidents or diseases trend and financial information. In the emergency area, two articles studies work the issue with the implementation of monitoring systems. Salap (2009) considers GIS applied to safety in underground mining, to



perform the dust concentration monitoring and ventilation requirements throughout a model developed in GIS with a web interface.

**Table 1.** Articles with SSHO topics

Author, year	Countries	Research area	Occupational sector	Analysis method	Program / Version
(Salap, Karslioğlu, & Demirel, 2009)	TR	Emergency	Mining	Monitoring air velocity	Not reported
(El-Harbawi et al., 2010)	MW	Chemicals - flammable (emergency) / toxic	Chemical and petroleum	Simulation of various mathematical models for different types of risk	ArcGIS
(Huang, Zhu, & Lu, 2010)	CN	Emergency	Mining	Monitoring gases (CH <sub>4</sub> , CO <sub>2</sub> ) and conditions of ventilator equipment	WebGIS
(Manase et al., 2011)	UK	Accidents prevention	Construction	Process analysis and collected data on the occurrence of accidents	ArcView GIS 3.3
(Moridi et al., 2015)	AU, JP	Temperature, humidity, and concentration of gases	Mining	Monitoring temperature, humidity, and gases	ArcGIS (not reported version)
(Delaunay et al., 2015)	FR, ZA, BE, UK	Ergonomic risks, Ionizing Radiation, Noise; Electromagnetic Fields of danger	Microelectronics	Analysis of samples/measurements	ArcGIS (not reported version)
(Kouame, Jiang Feng, & Zhu, 2017)	CN	Biohazards	Mining (Artisanal)	Monitoring real-time	Not reported

The database integrated WebGIS also supports, in case of an accident, the real-time decision on escape routes. This interface was chosen because it allows users to monitor and control critical data anytime from anywhere. Huang, Zhu, & Lu (2010) present the design and implementation of ZigBee technology-based system and Web GIS underground mining location. The system is intended to assist the rescue of victims at work in the event of disaster or accident through records of users in the network monitoring. Regarding the issues of chemical, physical, biological, ergonomic and accident, they were found four articles that work these risks were found. El-Harbawi et al. (2010) developed the “simulation of chemical industrial accident – SCIA” software, GIS in conjunction with Visual Basic language, modeling the accidental release of flammable and toxic chemicals. These templates can be used to check the risks of radiation, pressure and toxic dispersion different scenarios. Moridi et al. (2015) address the sensing, capture, processing and sending information through Zigbee with GIS in mining areas. The information measured by sensors is collected by Zigbee wireless through us and sent to the GIS. It generates a risk management system in real time, sending alarm messages and warning to those involved in the activity. Delaunay et al. (2015) map the risks in an industrial plant showing the causative agents. It addresses the importance of GIS use for mapping of risks within the aluminum industry. Integrated maps obtained information from risk agents with information layers of the type of agent, amount of people, cases of disease/injury, allowing an integrated view of these factors. Kouame et al. (2017) use medical data in combination with GIS to reduce the risk of proliferation of epidemics and infectious diseases, identifying outbreaks of disease in people who work in mining, as well as control and reduce disaster mines during the operation. In general, the works that deal with real-time monitoring are more applicable in identifying conditions that exceed exposure limits and emergency management. In conjunction with the

Web interface is shown to be efficient for decision making and verification of the conditions for all levels of management. Additionally, the introduction of new technologies aggregated to the GIS, such as the structure assembled with Zigbee, makes it possible to broaden the research field for new types of assessment.

## CONCLUSIONS

The search gave seven articles, including five in the search data and two based on the review of its references. Countries with more researchers within the collected articles are China and the United Kingdom, and the identified research areas include occupational safety and hygiene and emergency issues. Most studies used the ArcGIS program, but without identifying its version. The absence of this information makes it difficult to replicate the performed work (original version and updated version of the program) to check if there have been significant improvements in responses after the software update. The review presents relevant studies developed in GIS, and with application in the analysis area, and risk management and emergencies, even if they were not specifically addressed by the occupational safety and hygiene field. The applications found in GIS were only applied in industries, which invested values in the prevention of accidents and injuries are reduced when related to the occurrence of accidents on an industrial scale (Albert & Hallowell, 2013). Finally, it can be verified that the concept of an integrated and dynamic risk analysis using GIS is feasible, since there is already experience in the application of the platform within the theme, and the knowledge acquired in other areas can be used as well as the existing approaches to support the development of new techniques.

## References

- Albert, A., & Hallowell, M. R. (2013). Safety risk management for electrical transmission and distribution line construction. *Safety Science*, 51(1), 118–126. <https://doi.org/10.1016/j.ssci.2012.06.011>
- Delaunay, M., van der Westhuizen, H., Godard, V., Agius, R., Le Barbier, M., Godderis, L., & Bonneterre, V. (2015). Use of GIS in visualization of work-related health problems. *Occupational Medicine*, 65(8), 682–692. <https://doi.org/10.1093/occmed/kqv152>
- El-Harbawi, M., Mustapha, S., Choong, T. S. Y., Rashid, Z. A., Rashid, S. A., & Sherif, A. A. (2010). SCIA: GIS-based software for assessing the impacts from chemical industrial accidents. *Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management*, 14(2), 104–114. [https://doi.org/10.1061/\(ASCE\)1090-025X\(2010\)14:2\(104\)](https://doi.org/10.1061/(ASCE)1090-025X(2010)14:2(104))
- ESRI. (2019). What is GIS? Retrieved April 12, 2019, from <https://www.esri.com/en-us/what-is-gis/overview>
- Huang, X., Zhu, W., & Lu, D. (2010). Underground miners localization system based on ZigBee and WebGIS. 2010 18th International Conference on Geoinformatics, Geoinformatics 2010, 1–5. <https://doi.org/10.1109/GEOINFORMATICS.2010.5567542>
- Kouame, K. J. A., Jiang, F., Feng, Y., & Zhu, S. (2017). The Strengthening of Geological Infrastructure, Research and Data Acquisition - Using Gis in Ivory Coast Gold Mines. *MATEC Web of Conferences*, 95, 18001. <https://doi.org/10.1051/mateconf/20179518001>
- Manase, D., Heesom, D., Oloke, D., Proverbs, D., Young, C., & Luckhurst, D. (2011). A gis analytical approach for exploiting construction health and safety information. *Electronic Journal of Information Technology in Construction*, 16, 335–356. Retrieved from <https://www.scopus.com/inward/record.uri?eid=2-s2.0-79954487340&partnerID=40&md5=7194db4d8cbbf3f19a60b02043356ac2>
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., Altman, D., Antes, G., ... Tugwell, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement (Chinese edition). *Journal of Chinese Integrative Medicine*, 7(9), 889–896. <https://doi.org/10.3736/jcim20090918>
- Moridi, M. A., Kawamura, Y., Sharifzadeh, M., Chanda, E. K., Wagner, M., Jang, H., & Okawa, H. (2015). Development of underground mine monitoring and communication system integrated ZigBee and GIS. *International Journal of Mining Science and Technology*, 25(5), 811–818. <https://doi.org/10.1016/j.ijmst.2015.07.017>
- Şalap, S., Karslioğlu, M. O., & Demirel, N. (2009). Development of a GIS-based monitoring and management system for underground coal mining safety. *International Journal of Coal Geology*, 80(2), 105–112. <https://doi.org/10.1016/j.coal.2009.08.008>

# Work accidents with biological material with health professionals in Brazilian hospitals

Trajano F. B. X. Silva<sup>1</sup>, Humberto Costa<sup>2</sup>, Marcelo M. Ribeiro<sup>3</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT (up201802228@fe.up.pt) ORCID 0000-0001-7168-4161, <sup>2</sup>Faculty of Engineering, University of Porto, PT (humbertocosta@gmail.com) ORCID 0000-0003-0329-9004, <sup>3</sup>Faculty of Engineering, University of Porto, PT (marcelomontebello@gmail.com) ORCID 0000-0003-4945-5172

[https://doi.org/10.24840/978-972-752-260-6\\_0119-0122](https://doi.org/10.24840/978-972-752-260-6_0119-0122)

## Abstract

**Introduction:** The occupational accident (OA) can be characterized as an accident resulting from the exercise of work in the service of a public or private institution, which can cause permanent or temporary physical injury or permanent disability, with consequent loss or reduction of the capacity for work. Biological risk is the main form of exposure of the professional, and the main form of exposure of the health professional to biological risks occurs when there is direct or indirect manipulation of biological material (BM), which can contribute to the transmission of pathogens and, in this way, bring several problems to the contaminated individuals. **Objective:** This study aimed to characterize the national studies produced in the last 5 years that address accidents and exposure to biological material in a hospital environment. **Methodology:** A narrative literature review was carried out in a 5 years period, excluding articles that did not address the topic, articles written in a language other than Portuguese, studies conducted outside the Brazilian context, and any publication that was not peer-reviewed. **Results and Discussion:** The articles analyzed exposed the Brazilian reality, showing that the exposure to biological material is, in most cases, by contact with blood and biological accidents are related, in most cases, to the manipulation of puncturing materials. Re-encapsulation of needles was the main type of action that resulted in accidents. In relation to professionals, negligence, fatigue and distraction on the part of the professional, as well as the inappropriate use of personal protective equipment and work overload were the most cited points. **Conclusion:** The work environments involved in the studies were generally described as unfavorable to workers' health, mainly because they added innumerable intervening factors, such as the technological gap and the lack of maintenance of the instruments of work, precarious ways of organizing work, lack personal protective equipment in adequate quantity and quality. The training is, in general, performed, but it is important to develop the initial training program and continuing education institutions and taxation of companies that do not comply with regulatory mandates for the prevention of occupational accidents. Adequate working conditions, personal protective equipment in adequate quantity and quality are also important factors that must be demanded from health institutions.

**Keywords:** Occupational accident, Exposure to Biological Agents, Worker's health, Occupational Hazards.

## INTRODUCTION

The occupational accident (OA) can be characterized as that arising from the exercise of the work in the service of an institution, which can cause in the worker a bodily injury or permanent or temporary functional disorder, with consequent loss or reduction of the capacity for work. The consequences of accidents and occupational injuries include physical, economic and psychological damages to workers and their dependents, and may even lead to death in certain cases (Mbarki et al, 2013). Hospitals are characterized as health institutions (HS) that provide services to human health, including counseling, clinical, surgical and/or psychiatric consultations and treatment services for the healthy, sick and injured (Akagbo et al., 2017). They are classified as high-risk workplace. They are characterized by a high level of exposure to hazardous agents, which significantly endangers the health and life of workers, patients and community members if they are not adequately treated (Araujo et al., 2018; Pruss et al., 2014). The inappropriate or even non-management of these dangerous agents has clear implications for human health and the environment. It is clearly identified the need for attention with these agents, translating into the reduction of potential risk (Patil et al, 2005; Sousa, 2016; Silva, 2017). The main emphasis is given to biological risks, since they are the main form of professional exposure when directly or indirectly manipulating biological material (BM), resulting from health care (Manetti, 2006; Balsamo, 2006). Exposure to BM, whether through contact with body fluids or injuries caused

by sharp instruments, can contribute to the transmission of pathogens and thus bring various problems to contaminated individuals (Marziale, 2004). Based on the information previously presented, with the frequent occurrence of work accidents with biological material and in order to contribute to the knowledge of this type of accident, this study aimed to characterize the national studies produced in the last 5 years that address accidents and exposure to biological material in a hospital environment.

## METHODOLOGY

The method used to draw this research was a narrative literature review, covering the period between 2014 and 2018, of the scientific productions on accidents with exposure to biological material occurred in Brazil. The search was done in the databases LILACS and SciELO, using the descriptors (ok keywords) "Occupational accident, Exposure to Biological Agents, Worker's health and Occupational Hazards". In order to obtain recent and exclusively Brazilian data, it was decided to establish as exclusion criteria: articles that did not address the topic, articles written in a language other than Brazilian Portuguese, articles outside the specified period, studies conducted outside the context and any publication that was not peer-reviewed.

## RESULTS AND DISCUSSION

First, 47 articles were separated, which, after applying the exclusion criteria (period of time, original language, studies conducted outside the context and any publication that was not peer-reviewed), resulted in 09 items analyzed. Duarte Valim (2014) carried out an investigation with 121 nurses from four hospitals, one of great size and the other three of small size. The method used was a self-administered questionnaire, with socio-demographic issues and related to work accidents. Regarding work accidents with exposure to biological material, 53.8% (n = 65) were victims, of which 65, 96.9% (n = 63) were exposed to puncturing materials. According to the author, the hospitals analyzed to carry out continuous training with the employees, however, the numbers are very high. In the same period, Jefferson Martins (2014) carried out a survey of the prevalence of accidents in a city of São Paulo, with dentistry professionals. The data collection was performed through reports of work accidents involving biological material between 2007 and 2011. Of the total number of reports, the most reported exposure was percutaneous (95.2%) and blood was the biological material reported in most reports (88.6%). According to the author, the number of notifications was below the expected average, being able to characterize under notifications. Also in the same year, Martins Mendonça (2014) collected data through direct observation for 3 months, where there were eight exposures to biological material, 5 related to blood and 3 related to vomiting. However, there were no biological accidents in the period. The cases of exposure occurred due to the lack of use of the protective equipment, demonstrating an undervaluation of these barriers by the workers. The following year, Camilo (2015) carried out a cross-sectional study evaluating reports during the period from 2010 to 2013. Accidents were percutaneous in 30 (88.2%) cases and by mucosal contact in 4 (11.7%). Accidents with biological material were more frequent in auxiliary professionals/nursing technicians, during the surgical act and manipulation of the instruments after surgery. Also in the same period, Costa (2015) carried out a documentary analysis in the period from 2007 to 2011, in order to raise the number of accidents with the nursing team. Of the 27 accidents occurred in the period, 21 occurred with residents, demonstrating the need for greater care with less experienced workers. Alves (2016) carried out a cross-sectional study where he identified that of the 28 participants, 12 (42.8%) suffered at least one accident with biological material during the professional exercise. The majority of the exposures were

percutaneous (91.7%), the blood was the most frequently involved fluid (75%). Regarding the procedure, 75% of the individuals were administering medication at the time of the accident and 50% admitted that they were reattaching used needles. A descriptive study, analyzing 284,877 notifications of the National system of injuries for 5 years, conducted by Moura D'Almeida Miranda (2017), indicated that the highest incidence density occurred in female subjects with 0.8 cases per 1,000 workers / year ( $n = 222,042$ , 77.9%); in the age group of 20 to 24 years old, with 0.6 cases per 1,000 workers / year ( $n = 64,221$ , 23.3%); with incomplete high school and higher education, with 0.6 cases per 1,000 workers / year ( $n = 141,275$ , 49.6%). On the other hand, Soares (2018) aimed to determine the incidence of sharps injuries in health professionals in the city of Cacoal / RO, noting that the nursing team represented 75.97% of the cases. Regarding the time of the accident, it was verified that there was a higher incidence during the handling of the box with a sharps material (19.62%), the needle with lumen being the major causative agent (51.92%) and blood the material with a higher incidence (72.12%) of the samples. In the same period, Lima (2018) proposed to identify the occupational risks of nursing professionals in the Materials and Sterilization Centers, performing an exploratory, quantitative study carried out on 77 nursing professionals from the Materials and Sterilization Centers of two public hospitals where it was noticed that among biological risks, 67 (95%) were vulnerable to infections. The investigation of Duarte Valim (2014) and Jefferson Martins (2014) was carried out in the same year, but in different locations. However, the results are very close, reporting that most accidents with biological material recorded (96.9% and 95.2%, respectively) were by sharp instruments. The data suggest that the prevalence of this type of accident is evident. The authors suggest that the main causes of these accidents may be related to the lack of continuous training and also by the devaluation of safety standards by the workers. The results obtained by Martins Mendonça (2014) corroborate with the authors' evaluation. In 2016, Alves found somewhat lower values with sharp instruments (91.7%), but still very high values. It can not be said that the results are better than the reports of 2014, because the sample seems to be very small to be compared with the other studies. Unfortunately, the works of Moura D'Almeida Miranda (2017), Lima (2018) and Soares (2018) fail in some aspects, and the first and second study begins only evaluating the records of cases of injury by sharp materials, not comparing this data with work-accident data as a whole, thus creating an empty data gap. The same occurs with the third author, reporting all types of accidents to which the professional is exposed, but without indicating how many of these risks are related to accidents with sharp instruments. The authors Camilo (2015), Costa (2015) and Moura D'Almeida Miranda (2017) related a higher incidence of accidents with sharps materials to workers with less experience and less knowledge. Based on this information, indicate that more training is needed for these workers and more information so that they are more aware of the hazards of the work environment. But the overconfidence of more experienced workers has also been suggested as a source of accidents.

## CONCLUSIONS

The number of scientific papers on the subject of accidents with biological materials is small in relation to the size of the analyzed territory. The few articles have cut data on the subject and not reproduce the risks as a whole. A complete picture of the risks could focus where the factors that trigger the risk, to seek solutions in an effective way. Thus the institutions could assertively promote all the support and information necessary for the correct performance at work. At the same time, they could allocate investments directed towards programs of occupational health

responsibilities, contributing to the mitigation of the risks of accidents and accidents in this sector, fostering a sense of responsibility regarding their safety and health.

## References

- Akagbo, S. E., Nortey, P., & Ackumey, M. M. (2017). Knowledge of standard precautions and barriers to compliance among healthcare workers in the Lower Manya Krobo District, Ghana. *BMC research notes*, 10(1), 432. doi:10.1186/s13104-017-2748-9
- Alves, A. P., Diego Oliveira Miranda, E G, Canini S R M S. (2016) Acidentes ocupacionais com profissionais de enfermagem de um serviço de atenção domiciliar do interior paulista. *Rev. eletrônica enferm* 18: 1-9.
- Araújo, L. C. N., do Nascimento, A. S. S., de Moraes Calheiros, J., Santos, A. K. A. A., da Silva, M. B. (2018). Os acidentes de trabalho com materiais biológicos entre os profissionais de enfermagem. *Gep News*, 2(3), 10-16.
- Balsamo, A. C., & Andres Felli, V. E. (2006). Estudo sobre os acidentes de trabalho com exposição aos líquidos corporais humanos em trabalhadores da saúde de um hospital universitário. *Revista Latino-Americana de Enfermagem*, 14(3).
- Camilo, E N R, Arantes, T E F & Hinrichsen, S L. (2015). Análise epidemiológica dos acidentes com material biológicos em um hospital oftalmológico. *Revista Brasileira de Oftalmologia*, 74(5), 284-287.
- Costa, L P, P R dos Santos, Lapa A T, Spindola T (2015). Acidentes de trabalho com enfermeiros de clínica médica envolvendo material biológico. *Revista Enfermagem UERJ* 23.3 (2015): 355- 361.
- Duarte Valim, M., Palucci Marziale, M. H., Hayashida, M., & Richart-Martínez, M. (2014). Ocorrência de acidentes de trabalho com material biológico potencialmente contaminado em enfermeiros. *Acta Paulista de Enfermagem*, 27(3).
- Jefferson Martins, R, Saliba Moimaz, S A, Isper Garbin, A J, Vicente G, Patrick R, & Saliba Garbin, C A. (2014). Prevalência de Acidentes Com Material Biológico em um Município do Noroeste de São Paulo, Brasil, no Período de 2007 a 2011. *Ciencia & trabajo*, 16(50), 93-96.
- Lima, M D P, Chaves B J P, Lima V S, Silva P E, Soares N S C S, Santos I B C. (2018). "Riscos ocupacionais em profissionais de enfermagem de centros de material e esterilização." *Revista Cuidarte*, 9(3), 2361-2368.
- Manetti, M L. "Prevenção de acidentes de trabalho com material biológico segundo o modelo de Green e Kreuter." *Revista Gaúcha de Enfermagem* 27.1 (2006): 80.
- Martins Mendonça, K, Ferreira Veiga Tipple, A, Custódia Silva e Sousa, A, Severino Pereira, M, & Rapparini, C. (2014). Acidentes com material biológico em serviços de urgência e emergência. *Ciencia y enfermería*, 20(2), 65-71
- Marziale, M H P, Nishimura K N and Ferreira M M. "Riscos de contaminação ocasionados por acidentes de trabalho com material pérfuro-cortante entre trabalhadores de enfermagem." *Revista Latino-Americana de Enfermagem* 12.1 (2004): 36-42.
- Mbarki, A.; Kabbachi, B.; Ezaidi A. and Benssaou, M. (2013) "Medical Waste Management: A Case Study of the Sous-Massa-Drâa Region, Morocco," *Journal of Environmental Protection*, Vol. 4 No. 9, 2013, pp. 914-919.
- Moura D'Almeida Miranda, F, Cruz E D A, Félix J C V, Kalinke L P, Mantovani M F and Sarquis L M M. (2017). "Perfil dos trabalhadores brasileiros vítimas de acidente de trabalho com fluidos biológicos." *Revista Brasileira de Enfermagem* 70.5
- Patil GV, Pokhre K. (2005) Biomedical solid waste management in an Indian Hospital: A case study. *Waste Manag*;25:592-9.
- Pruss A, Giroult S, Rushbook P (2014) Safe management of waste from healthcare activities. Geneva: World Health Organization.
- Silva, N F C, Vianna, Mello C M, Oliveira, F S G, Mosegui, G B g, & Rodrigues, M P S. (2017). Fuzzy Visa: um modelo de lógica fuzzy para a avaliação de risco da Vigilância Sanitária para inspeção de resíduos de serviços de saúde. *Physis: Revista de Saúde Coletiva*, 27(1), 127-146.
- Soares, W K R, Mota W H, Kuster D E, Cavalcante A B L, (2018). "Incidência de acidentes com perfurocortantes em profissionais de saúde em um hospital de grande porte na Amazônia Legal/Incidence of accidents with perforocortants in health professionals in a hospital of great port in the Legal Amazon." *Brazilian Journal of Health Review*, 1(1), 51-69.
- Sousa, A P L, Queiroz, A A F L N, Oliveira, L B, Moura, (2016). Representações sociais da Enfermagem sobre biossegurança: saúde ocupacional e o cuidar prevencionista. *Revista Brasileira de Enfermagem*, 69(5), 864-871

## Ergonomic analysis of cleaning professionals: pilot study

Solange dos Santos<sup>1</sup>, J. Duarte<sup>2</sup>, A. D. Lucena<sup>3</sup>, J. C. Guedes<sup>4</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT (solangel442@gmail.com) ORCID 0000-0002-2475-198X, <sup>2</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (jasduarte@fe.up.pt) ORCID 0000-0002-5856-5317, <sup>3</sup>Federal Rural University of Semiarid, BR (andre lucena@ufersa.edu.br) ORCID 000-0003-0181-4260, <sup>4</sup>Associated Laboratory for Energy, Transports, and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT (jccg@fe.up.pt) ORCID 0000-0003-2367-2187  
[https://doi.org/10.24840/978-972-752-260-6\\_0123-0128](https://doi.org/10.24840/978-972-752-260-6_0123-0128)

### Abstract

**Introduction:** The cleaning activity is characterized by being an occupational activity performed mostly standing, adopting excessive bending of the lower back postures, high positioning of the arms, squatting, the repetitiveness of movements and use of non-ergonomic working tools that demand a high physical profile and agility of the worker. The physical, ergonomic, psychosocial and organizational factors are work-related risks for the emergence of musculoskeletal disorders. Being extremely demanding for the worker's musculoskeletal structure, the ergonomic analysis is fundamental. This pilot study aimed to assess the risk of musculoskeletal lesion of a professional cleaning worker due to the movements and task performance along the activity. **Methodology:** A cleaning professional was selected, observations in loco were made, and video/photos were collected, as well as anthropometric data and job-related information. The Nordic questionnaire was applied, and complemented by the REBA method. To determine the energy expenditure and prevent the appearance of injury it was performed an analysis with ActiGraph wGT3X-BT. In order to analyze the adopted postures, Microsoft Excel® and Actilife® software were used for data processing. **Results and discussion:** The results indicate that the worker has a high prevalence of painful symptomatology in the exposed regions due to the adopted postures, which may be indicative of musculoskeletal injuries. The study allowed to analyze the most affected body regions were the neck, hips/thighs, knees and ankles/feet. The ergonomic analysis revealed the working postures used during the activity constitute a high risk of musculoskeletal injury. **Conclusions:** The results are consistent with the existing literature and provide information that allows characterizing the working activity through the body segments: neck, shoulder, elbow, wrist / hand, chest area, lower back, hips / thighs, knees and ankles / feet according with the positions adopted by effectively working over the 8h of work. With the results, it is possible to know the risks ergonomic that the worker is exposed, as well as improvements and/or changes in the form of execution of the activity.

**Keywords:** Ergonomic Analysis, Professional Cleaning, Actigraphy, Repetitive Movements, Posture Assessment.

### INTRODUCTION

Professional cleaning is a physically demanding job that includes numerous and varied tasks, where workers are most of their time standing, lifting and/or pushing equipment. Thus, they undergo inadequate postures, repetitive movements and precarious situations (Dahlqvist, Nordander, Forsman, & Enquist 2018). Such activities do not require any training instructions (Kumar & Kumar, 2008). Several studies indicate that the cleaning tasks are characterized by static and repetitive muscle movements of the back, hands and legs, which leads to the necessity of using excessive strength or inadequate postures (Kalkis, Roja & Kalkis, 2014). These workers have a high risk of developing health problems, particularly musculoskeletal problems, especially affecting the back, neck, shoulders, elbows and hands (Wang, Chen, & Chiou, 2016). The risk of developing musculoskeletal injuries is multifactorial and is based on the level of physical activity of the workers not only within their occupational activity but also outside their work. This risk is developed through repetitive movements, inadequate postures, manual manipulation of loads, poor job conception (Wang et al., 2016). The actigraphy technique measured by the actigraphy wGT3X-BT allows the assessment of physical activity through parameters such as: energy expenditure, metabolic rate, activity level (sedentary, mild, moderate, vigorous, very vigorous), heart rate, magnitude vector description (x, y, z), step-by-minute counts, total sleep time, and to differentiate between sleep/awake periods through any body movement produced by skeletal muscles (Ribeiro, 2014). Therefore, it is possible to analyze movements and the execution of tasks (adopted postures) in the occupational activity

through two traditional methods, Nordic Questionnaire (prevalence of musculoskeletal symptoms) (Kuorinka et al., 1987), and REBA (Rapid Body Assessment) method (Hignett & McAtamney, 2000) and to validate these methods with the actigraphy technique and its parameters. So, this pilot study intended to analyze the positions adopted during the activity of a cleaning professional worker, assess the risk of musculoskeletal injury and determine the prevalence of musculoskeletal symptoms of the professional cleaning worker, to prevent the emergence of musculoskeletal injuries.

## MATERIALS AND METHODS

The ergonomic analysis was carried out on-the-job, to a professional cleaning worker at Faculty of Engineering University of Porto (FEUP). This job has been chosen, because the tasks have long time cycles and, usually, the workers adopt incorrect postures. Without ignoring the cognitive and organizational domains, it is emphasized in the present study the physical domain as it has concern for anthropometric, physiological and biomechanical information of human beings in contact with their working environment. The study was developed by observing the target and simultaneously collecting anthropometric data, photo, videos and job-related information. The collected videos and photographs were subsequently analyzed in detail and the tasks were analyzed, and the postures that contribute to an increased risk of musculoskeletal injuries at work were identified. After the definition of tasks and target posture analysis, the worker was questioned about whether he had pain, aching or discomfort in the last twelve months and the last seven days in nine anatomical regions, which were, neck, shoulder, elbow, wrist/hands, chest area, lower back, hips/thighs, knees, ankles/feet. Where the working rated the prevalence of symptoms in anatomical regions on a scale of one to ten, according to the Portuguese version of the Nordic Questionnaire (Mesquita, Ribeiro, & Moreira, 2010). The postures adopted by the working were analyzed according to REBA method (Rapid Body Assessment) (Kuorinka et al., 1987) applying six steps: observation of the task, postures assessed for EVALUATION, assign a score to the static postures, perform treatment of the score calculate the final score of the REBA and, lastly confirm the level of action and the urgency of the respective measures. The method uses a score sheet where they classified have classified body segments according to postures and activity levels of 1 to 15, scoring is done by two groups A and B where A (trunk, neck, legs) and B ( arms, forearms, wrists) (Hignett & Mc Atamney, 2000). It was used actigraphy (Actigraph WGT3x-BT) together with the heart rate monitor (Polar H7 Heart Rate), to evaluate the physical activity in temporal variations of the acceleration magnitudes of three individual planes (x, y, z). These accelerations were converted through the Actilife software to calculate energy expenditure (EE), metabolic rate (MET) and the cutoff points activities (Barwais, Cuddihy, Rachele, & Washington, 2013).

## RESULTS AND DISCUSSION

The employee works 8 hours/day, work starts at 09: 00h and has a 10 min break from 10: 00h to 10: 10h and then have another break for lunch from 12: 00h to 13: 00h and leaves at 17: 00h. Figure 1 highlights some of the adopted postures by the professional cleaning worker during her activity: continuous dynamic muscle movement in the limbs under overload; repetitive or continuous movements, some under overload anteflexion and twisting of the spine; inadequate posture of the spine, knees and ankles; lack of working of awareness about the importance of minimizing occupational risk.



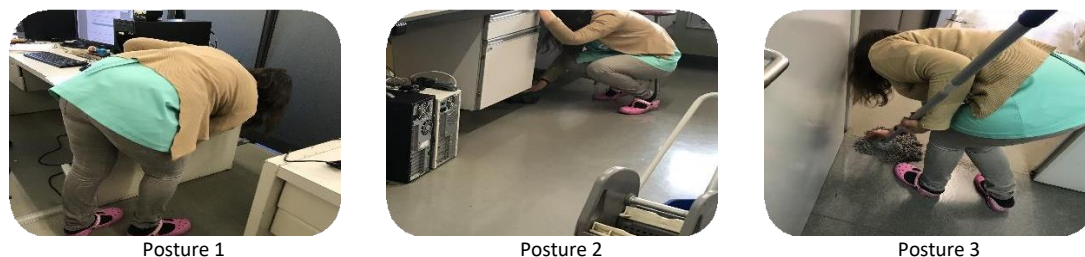


Figure 1. Adopted postures

The studied worker, while doing her activities, moved up for several hours with only two breaks (a 10 min for a snack in the morning and another one hour for lunch), mobilizing many myoarticular groups simultaneously or alternately in activities that required alternating postures, but all the time standing. In this case, although it is a dynamic activity, the standing posture determines a static load on the muscles that may contribute to the occurrence of pain in the lower limbs. This complaint was made by the worker through the Portuguese version of the Nordic questionnaire, indicating the prevalence of musculoskeletal injuries in one or more anatomical regions in a specific time interval, as shown in Figure 1. Pain intensity in different regions are represented as moderate pain, ranging between 4 and 5 on the neck and shoulders and regions with maximum intensity between 9 and 10 were lower back, hips/thighs and knees. These intensities prevail because the activity itself, and repetitive movements over the 25 years of work, requires working continuously with the anteflexion and torsion of the spine because of the handling of the broom, squeegee or can clean underneath the tables and under the cabinets. Professional cleaning is a dynamic job that requires a lot of muscle activity with repetitive movements and adoption of bad postures held for long, and for this reason the REBA analysis was done in two groups A (trunk, neck, legs) and B (arms, forearms, wrists), the data obtained by REBA software (Employee Assessment Worksheet) proceeded to REBA analysis for tasks selected by the method verified the activity constitutes a high risk for emergence of musculoskeletal injury (SCI) with the exception of work done with the forearm in which it was classified as low. According to this tool and its authors (Mesquita et al., 2010) the level of activity for the total score 13 dictates that are necessary to implement changes (Hignett & Mc Atamney, 2000).

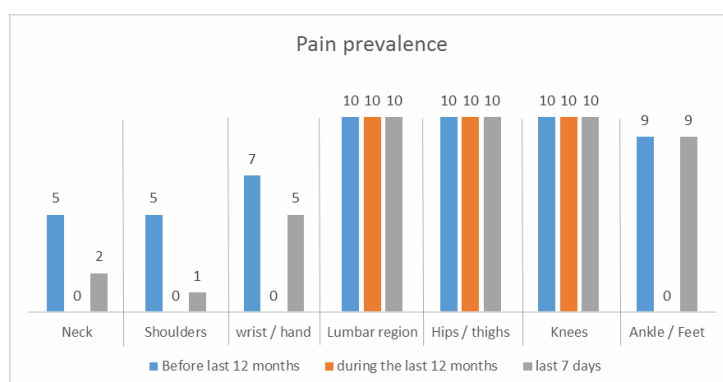


Figure 2. Pain prevalence

The magnitudes of the accelerations were calculated using the software Actilife for estimating energy expenditure by Equation Freedson VM3 combination (11). This software option combines Freedson VM3 equation (11) to the equation Williams Work-Energy (98). When the

VMCPM is less than 2453 counts per minute software uses Formula (1), and when the VMCPM is greater than or equal to 2453 it uses Formula (2), where VMCPM vector is the magnitude of counts per minute, CPM is counts per minute, BM is body mass in kg.

VM is the sum of  $\sqrt{((Axis\ 1)^2 + (Axis\ 2)^2 + (Axis\ 3)^2)}$

$$\frac{Kcal}{min} = 0,001064 \times VM + 0,087512 \times (BM) - 5,50022 \quad (1)$$

$$\frac{Kcal}{min} = CPM \times 0,0000191 \times (BM) \quad (2)$$

Energy expenditure was calculated in the waist and wrist area where the most representative values were pulse with an average of 3.14kcal / min, where there is discrepancy in the amount of time an average of 10h energy expenditure 3.85kcal / min, 11h averaging 4.00kcal/min, with an average of 13h 3.33kcal/min and 14h with an average 4.21kcal/min. According to La Riva Rodríguez(2016), energy expenditure in industrial activities shall not exceed the limit of 4.2kcal/min for men and 3.2kcal/min for women. This discrepancy of values concerning the wrist due to dynamic use of arms to the activity itself, as to perform all working tasks whenever you use the wrist (hand). Regarding the energy expenditure (EE) in metabolic rate (MET) was calculated using the software used Actilife considering the equation (3) Swartz Adult overground and lifestyle, where CPM is counts per minute (Swartz et al., 2000). Moreover, the result is an average of the results obtained at the waist (MET 2.24) and wrist (MET 3.65).

$$MET\ Rate = 2,660 + (0,0006863 \times CPM) \quad (3)$$

In short, 1 MET is the amount of energy that the human body uses at rest. For example, a rate of 2.0 MET, indicates that during this period, the individual spends twice its energy sedentary standard(Ainsworth et al., 2011). There discrepancy value on the pulse zone in hours 9, 10, 11, 13, 14, 15, the working spent four times its normal sedentary energy (BMR \* 4). However, tasks which involve the movement of the upper body, such as ironing, washing and sweeping the sheets may require a gross energy expenditure 2-4 METs (1 MET = 3.5 ml O<sub>2</sub> · kg<sup>-1</sup> · min<sup>-1</sup>) (Hendelman, Miller, Baggett, Debold, & Freedson, 2000). The hip accelerometer almost does not detect significant movement regarding the activity. Consequently, an accelerometer worn on the wrist may be able to explain the energy expenditure associated with the movement of the upper body involved in these types of tasks (Swartz et al., 2000). The metabolic rates (METs) are calculated using cut points for minutes (or ADCs) measured by the BT-ActiGraph wGT3X to rate the intensity of physical activity such as sedentary, mild, moderate and vigorous (Bai et al., 2016). To calculate the cutoff points the Actilife software used adult Freedson equation VM3 (2011) that utilize the values of the magnitudes of the accelerations per minute obtained by ActiGraph wGT3X-BT, and were classified as moderate activity movements in the axes y and z relative the wrist area. The values of the accelerations are more representative in the z-axis as the working always to fall and get up to perform their activities. The differences in counts per minute and metabolic rate (METs) similar activities are small and may be explained by external variability (BROOKS, GUNN, WITHERS, Gore, & PLUMMER, 2005). Additional studies are needed

to determine the validity of the regression equations and the cutoff points observed in both studies (Swartz et al., 2000).

## CONCLUSIONS

This study focused on the ergonomic analysis of movements and tasks (as well as adopted postures) of a worker in the context of professional cleaning, where stood out as risk factors, repetitiveness of the movements, anteflexion and torsion of the spine and dynamic work of the lower limbs that affect the routine of the worker. These factors are related to the symptomatology of pain and discomfort manifested by the worker through the Portuguese version of the Nordic questionnaire and by the analysis of postures and repetitive movements through the REBA method. It was verified that the worker exercises her activity with discomfort, according to the prevalence of symptomatology applied by the Nordic questionnaire, and is at risk of developing musculoskeletal disorders, determined by the level of risk of the REBA method. This is due to the lack of knowledge on ergonomic principles from the worker, the workload and the activity itself. This study recommends an ergonomic intervention, complemented with the appropriate training of the worker regarding occupational health education on more appropriate postural changes, implementation and/or updating of the standards to recommend and reduce the risk of musculoskeletal disorders injury. This pilot study aims to contribute to a future study that will determine whether there is any relation or possibility to infer about the development of musculoskeletal injury from the technique of actigraphy through the parameters assessed such as: energy consumption, metabolic rate, activity level (sedentary, mild, moderate, vigorous, very vigorous), heart rate, among other parameters, as well as any skeletal muscles movement that are not recorded and assessed through the photographs and videos, in order to predict the risk of musculoskeletal injury and physical recovery during a period of continuous activity.

## References

- Ainsworth, B. E., Haskell, W. L., Herrmann, S. D., Meckes, N., Bassett Jr, D. R., Tudor-Locke, C.,... Leon, A. S. (2011). 2011 Compendium of Physical Activities: a second update of codes and MET values. *Medicine & Science in Sports & Exercise*, 43(10), 1575–1581.
- Bai, J., Di, C., Xiao, L., Evenson, K. R., LaCroix, A. Z., Crainiceanu, C. M., & Buchner, D. M. (2016). An Activity Index for Raw Accelerometry Data and Its Comparison with Other Activity Metrics. *PLOS ONE*, 11(1), 1–14. <https://doi.org/10.1371/journal.pone.0160644>
- Barwais, F. A., Cuddihy, T. F., Rachele, J. N., & Washington, T. L. (2013). ActiGraph GT3X determined variations in “free-living” standing, lying, and sitting duration among sedentary adults. *Journal of Sport and Health Science*, 2(4), 249–256. <https://doi.org/https://doi.org/10.1016/j.jshs.2013.06.003>
- BROOKS, A. G., GUNN, S. M., WITHERS, R. T., Gore, C. J., & PLUMMER, J. L. (2005). Predicting walking METs and energy expenditure from speed or accelerometry. *Medicine & Science in Sports & Exercise*, 37(7), 1216–1223.
- Dahlqvist, C., Nordander, C., Forsman, M., & Enquist, H. (2011). Self-recordings of upper arm elevation during cleaning - Comparison between analyses using a simplified reference posture and a standard reference posture. *BMC Musculoskeletal Disorders*, 19(1). <https://doi.org/10.1186/s12891-018-2328-8>
- de La Riva Rodríguez, J., Estrada, E. I., Reyes Martínez, R. M., & Prieto, A. W. (2016). Determination of energy expenditure of direct workers in automotive harnesses industry. In C. Schlick & S. Trzcieliński (Eds.), *Advances in Intelligent Systems and Computing* (Vol. 490, pp. 331–339). [https://doi.org/10.1007/978-3-319-41697-7\\_29](https://doi.org/10.1007/978-3-319-41697-7_29)
- Hendelman, D., Miller, K., Baggett, C., Debold, E., & Freedson, P. (2000). Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Medicine & Science in Sports & Exercise*, 32(9), S442–S449.

- Hignett, S., & Mc Atamney, L. (2000). REBA (Rapid Entire Body Assessment). *Applied Ergonomics*, 31, 201–205.
- Kalkis, H., Roja, Z., & Kalkis, V. (2014). Physical load analysis in hotel cleaning work. *Agronomy Research*, 12(3), 843–850. Retrieved from <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84901473231&partnerID=40&md5=c770e9167b47fc889621a637ff92e1dd>
- Kumar, R., & Kumar, S. (2006). Musculoskeletal risk factors in cleaning occupation-A literature review. *International Journal of Industrial Ergonomics*, 38(2), 158–170. <https://doi.org/10.1016/j.ergon.2006.04.004>
- Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., & Jørgensen, K. (1987). Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Applied Ergonomics*, 18(3), 233–237.
- Löfqvist, L., Osvalder, A.-L., Bligård, L.-O., & Pinzke, S. (2015). An analytical ergonomic risk evaluation of
- Mesquita, C. C., Ribeiro, J. C., & Moreira, P. (2010). Portuguese version of the standardized Nordic musculoskeletal questionnaire: cross cultural and reliability. *Journal of Public Health*, 18(5), 461–466.
- Ribeiro, J. C. R. D. (2014). Estudo dos Determinantes da Atividade Física objetivamente Avaliada durante as aulas de Educação Física de 45 E 90 minutos.
- Swartz, A. M., Strath, S. J., BASSETT, D. R., O'BRIEN, W. L., King, G. A., & Ainsworth, B. E. (2000). Estimation of energy expenditure using CSA accelerometers at hip and wrist sites. *Medicine & Science in Sports & Exercise*, 32(9), S450–S456.
- Thach, Elizabeth C., Thompson, Karen J., Morris, A. (2006). A fresh look at followership: A model for matching Followership and leadership styles. *Journal of Behavioral & Applied Management*, (1), 1–5. <https://doi.org/10.1007/s13398-014-0173-7.2>
- Villumsen, M., Madeleine, P., Jørgensen, M. B., Holtermann, A., & Samani, A. (2017). The variability of the trunk forward bending in standing activities during work vs. leisure time. *Applied Ergonomics*, 58, 273–280. <https://doi.org/10.1016/j.apergo.2016.06.017>
- Wang, M.-H., Chen, B.-H., & Chiou, W.-K. (2016). Redesign the cleaning tools from analysis of working postures at a cleaning job using the task analysis and OWAS methods. In *Advances in Physical Ergonomics and Human Factors* (pp. 417–426). Springer.
- Welk, G. (2002). Physical activity assessments for health-related research. *Human Kinetics*.

## Factors influencing workplace physical activity interventions: a short review

Sara Maheronnaghsh<sup>1</sup>, Joana Santos<sup>2</sup>, Mário Vaz<sup>3</sup>

<sup>1</sup>Faculty of Engineering, University of Porto, PT ([up201600476@fe.up.pt](mailto:up201600476@fe.up.pt)), <sup>2</sup>Research Centre in Health and Environment (CISA), School of Health, Polytechnic Institute of Porto, PT ([jds@ess.ipp.pt](mailto:jds@ess.ipp.pt)), <sup>3</sup>Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering, University of Porto, PT ([gmavaz@fe.up.pt](mailto:gmavaz@fe.up.pt)) ORCID 0000-0002-6347-9608  
[https://doi.org/10.24840/978-972-752-260-6\\_0129-0134](https://doi.org/10.24840/978-972-752-260-6_0129-0134)

### Abstract

**Introduction:** Many occupations are characterized by sedentary behavior (SB) and lack of physical activity (PA). There is growing evidence that prolonged sitting is associated with multiple health risks, including musculoskeletal disorders, biomarkers of increased cardiovascular diseases, some forms of cancer. There is an increasing interest in changing the work environment by implementing various interventions to reduce barriers and promote physical activity. The aim of this short review is to identify factors that affected workers' SB and/or PA to design appropriate interventions. **Methodology** The search was performed based on PRISMA statement methodology and was conducted in Scopus for articles and reviews published in scientific journals from 2010 until 2019 in English, using a set of root keywords as "sedentary work," "physical activity" and "effectiveness intervention". **Results and discussion** the review included 12 studies describing effective factors on PA in three categories: organizational factor, individual factor, and social factor. The main organizational factors found were: supportive workplace policies and resources, time for involvement in intervention, paying for activity, management support, work environment factors, and job type (passive jobs, and high-strain jobs). Interpersonal factors, knowledge include (educational level and information about physical activity guidelines) and some sociodemographic factors as individual factors associated with the physical work activity. Furthermore, social factors like social support and social norm have a significant effect on willing to do physical activity in workers. Some studies used "behavior change techniques" to find effective factors on physical activity for identifying the most appropriate interventions. **Conclusion:** Current evidence demonstrates that some individual, organizational and social factors influence work physical activity; therefore, they need to be considered in each population specifically, before choosing the intervention type. It can contribute to the increasing effectiveness of interventions intended to improve physical activity. Future research in this area should consider the association of various factors identified to enhance the effectiveness of interventions.

**Keywords:** Sedentary work, Effectiveness of the intervention, Sociodemographic factors.

### INTRODUCTION

People who spend most of their working hours in sedentary work are at higher risk for adverse health effects, even if they exercise the same amount as those with a less sedentary lifestyle (Bankoski et al., 2011; Finni, Haakana, Pesola, & Pullinen, 2014). Sedentary behavior is increasingly present in people's professional lives, because of the changing nature of jobs (e.g., shift from manufacturing to services, using technology). Nowadays, workers spend up to 70% to 90% of the workday in a static sitting posture (Smith, Ekelund, & Hamer, 2015) and they are exposed to ergonomic risk factors (Thorp et al., 2012). Increasing occupational sitting time has been associated with a decrease of 100 calories per day, which, in turn, resulted in a reduction of the energy expenditure by the workers (Cleland et al., 2013; Mullane et al., 2017). It can cause 80% of the average increase in body weight among workers during this period (Church et al., 2011) and increase of about 5% in the risk of obesity and 7% increase in the risk of diabetes. There is growing evidence that prolonged sitting is associated with multiple health risks, including musculoskeletal disorders, biomarkers of increased cardiovascular diseases, some forms of cancer (Gao, Nevala, Cronin, & Finni, 2016). Previous studies show that a wide variety of these outcomes can be treated or improved through increasing physical activity. Some different strategies like physical changes, policy changes, information, and counseling or multiple interventions (Neuhaus, Eakin, et al., 2014) are being designed over the years to promote physical activity at work. Depending on the characteristics of the tasks/workplace, different types of active workstations can be implemented such as walking on a treadmill in workstation (Levine & Miller, 2007; Tudor-Locke, Schuna Jr., Frensham, & Proenca, 2014) and

using sit-stand desk (Chau et al., 2016; E. F. Graves, C. Murphy, Shepherd, Cabot, & Hopkins, 2015; Gao et al., 2016). Also, different studies evaluated the effects of changes in chairs to enable more activity, such as balloon chairs (Beers, Roemmich, Epstein, & Horvath, 2008), using cycle workstation (Rovniak et al., 2014; Sabia & Anger Jr., 2016). Some other intervention, such as changing the layout of the workplace, to make possible perform more physical activity (Commissaris, Douwes, Schoenmaker, & de Korte, 2006). Interventions should ensure promising effects, to effectively change habits and arouse the interest of the employers and employees, therefore for choosing appropriate and practical intervention components, effective factors on changing physical activity habit should be considered (Buman et al., 2017). In this short review, various factors that affected workers' SB and/or PA and will be identified.

## METHODOLOGY

This short review of the literature was based on the PRISMA statement methodology. The research was performed in Scopus, science direct and other resources, and included all articles and review papers published in scientific journals from 2010 until 2019 April in English. The following criteria were used to include articles: (1) At least one of the following words must be present in Title, Abstract or Keywords: "descriptive epidemiology", "interventions", "effectiveness", "socioecological factor", "improve physical activity", "workplace", "epidemiology", and the roots "physical activity", "sedentary work"; (2) Any of the following words should be present neither Title nor Keywords: "daily life", "clinical", "elderly". The outcomes of different keyword combination and sources were merged, taking care to discard the duplicates, into a single list of documents, excluding all records, which were not full papers, open access or just protocol.

## RESULTS

The total number of papers, before exclusion was 389. Additionally, four records were identified through other sources. The total number of papers after eliminated duplicate were 380 and 12 papers were matched with the search criteria. Two systematic reviews were found on this topic. Most of the discarded papers focused on interventions and affection of them on organizational factors like productivity and job satisfaction or individual factors such as improving knowledge about sedentary behavior, or they were measure association between interventions and physical activity; other papers were eliminated because they focused on daily life and clinical scope or elderly people. Studies were quite large, including 23 to 654 participants (Batista Ferrer, Cooper, & Audrey, 2018). Two studies used "behavior change Techniques" to find effective factors for identifying the most appropriate interventions for improving physical activity (Munir et al., 2018; Perchoux et al., 2017). Other studies used various questionnaires to evaluate PA and SB at the workplace and also to collect individual and sociodemographic information, psychological parameters and job type. As a result, they characterized PA and individual and organizational factors (Batista Ferrer et al., 2018; Clemes et al., 2016; McNaughton, Crawford, Ball, & Salmon, 2012; Perchoux et al., 2017). Four studies used the accelerometer to collect data about physical activity instead of a questionnaire (Batista Ferrer et al., 2018; Brett & Pires-Yfantouda, 2017). All studies considered the effect of individual factors on physical activity, whereas six studies evaluated organizational factors and just three studies searched about social factors.

## DISCUSSION

Recent literature has begun to emphasize the importance and potential of using socio-ecologically based approaches to choose effectiveness intervention in the workplace, due to the decrease of physical activity in the workplace and the increase in the implementation of different interventions. Two studies used comprehensive ecological frameworks (i.e., the Ecological Model of Physical Activity; EMPA and (Plotnikoff, Prodaniuk, Fein, & Milton, 2005) method) for understanding PA and effective factors in the workplace (Plotnikoff, Pickering, Flaman, & Spence, 2010). In this framework, six environment levels in the workplace are identified that may influence on physical activity: (a) individual (i.e., demographic factors and individual employee characteristics related to PA behaviors such as skills, knowledge, confidence, age, and gender). (b) social (i.e., the influence of the corporate culture, social relationships, supervisor relationships related to PA behavior of employees). (c) organizational (i.e., infrastructure, leadership, and desire of the workplace to promote PA, how the organization is structured). (d) Community (i.e., how the workplace interacts effect on PA behavior of employees), (e) policy (i.e., the workplace's policies regarding employees' PA behavior), and (f) physical environment (i.e., the physical environment of the workplace including the buildings, workplace layout, and surrounding area related to PA behavior of employees). Although ecological models of PA suggest that environments may have a direct influence on physical activity behavior, these models also propose that environmental influences on PA may be influenced with psychological variables such as beliefs and other factors (Plotnikoff et al., 2010). Munir et al. (2018) described the systematic process to develop the intervention components to change sitting behavior specifically in the workplace. They used the Behavior Change Wheel (BCW) (Susan Michie, van Stralen, & West, 2011) and its functions to enhance the development of the intervention. The BCW is a comprehensive framework for designing interventions by integrating behaviour theory to understand and target mechanisms of action within the intervention (S Michie, Atkins, & West, 2015). The wheel has three layers; including Capability (physical and psychological), Opportunity (social and physical) and Motivation (automatic and reflective). The second layer of the BCW comprises nine intervention functions (Education, Persuasion, Incentivisation, Coercion, Training, Enablement, Modelling, Environmental Restructuring, and Restrictions) (Munir et al., 2018). They found that in their study, motivation to change behavior was low because of current working habits and the work culture of sitting. Their findings are also similar to those of Neuhaus et al. (Neuhaus, Healy, et al., 2014) but they recognized the importance of social opportunity and social influence in reducing sitting at work. They suggested that knowledge, social identity, intentions, beliefs about capabilities, and self-regulation of behavior were essential to address in their intervention. Also, they indicate that the BCW guide can be applied successfully in the context of designing a workplace intervention for increasing PA. Scotland's new Strategy for Physical Activity, "Let's make Scotland more active" (Executive, 2003), aimed at increasing and maintaining the proportion of physically active people in Scotland. This study suggests that three conditions are necessary to enable behavior change in physical activity: high self-efficacy, a firm intention and readiness to change, and a supportive social network and environment with no barriers. Caroline E. et al (2017) researched to examine the effectiveness of a pedometer-based intervention to increase walking behaviour amongst staff at a Scottish university. They realized that academic staff was more likely to report that work pressures – such as teaching, lunchtime meetings, or urgent deadlines for grant applications or journal articles – precluded regular daytime walking. Indeed, individual and organizational factors effect on the amount of physical activity (Brett & Pires-Yfantouda, 2017). Clemes et al. (2016) analysed the influence of

sociodemographic factors on sedentary behaviour to inform effective interventions. They examined domain-specific sitting times reported across socio-demographic groups of office workers. It was observed that sedentary behaviors were most prevalent amongst males, younger adults, obese individuals, individuals educated up to school level, those not meeting physical activity guidelines, single/divorced/widowed adults, full-time workers, and high work-time sitters. They suggested that these sociodemographic groups should be targeted for interventions designed to reduce sedentary behaviour.

## CONCLUSIONS

Previous studies show that a wide variety of adverse effect of sedentary work can be treated or improved through increasing physical activity. To identify the most appropriate and user friendly interventions for improving physical activity, effective factors on amount of physical activity need to be defined. This short review search about various factors that affected workers' SB and/or PA and their methods. It has shown that a few comprehensive studies have been conducted in this field, but results suggest that to maximize the effectiveness of interventions for increasing PA, researchers should evaluate effective factors on physical activity and recognize barriers to participation among different classification of employees; specific needs for each job type should also be considered. By considering individual, organizational and social factors, interventions will be more effectiveness and acceptable and participation in the plan for increasing physical activity will be optimal. Future research should consider the association of various factors with the amount of physical activity through the identified techniques in different population and organizations to enhance the effectiveness of interventions.

## References

- Bankoski, A., Harris, T. B., McClain, J. J., Brychta, R. J., Caserotti, P., Chen, K. Y., ... Koster, A. (2011). Sedentary activity associated with metabolic syndrome independent of physical activity. *Diabetes Care*, 34(2), 497–503. <https://doi.org/10.2337/dc10-0987>
- Batista Ferrer, H., Cooper, A., & Audrey, S. (2018). Associations of mode of travel to work with physical activity, and individual, interpersonal, organisational, and environmental characteristics. *Journal of Transport and Health*, 9, 45–55. <https://doi.org/10.1016/j.jth.2018.01.009>
- Beers, E. A., Roemmich, J. N., Epstein, L. H., & Horvath, P. J. (2008). Increasing passive energy expenditure during clerical work. *European Journal of Applied Physiology*, 103(3), 353–360. <https://doi.org/10.1007/s00421-008-0713-y>
- Brett, C. E., & Pires-Yfantouda, R. (2017). Enhancing participation in a national pedometer-based workplace intervention amongst staff at a Scottish university. *International Journal of Health Promotion and Education*, 55(4), 215–228. <https://doi.org/10.1080/14635240.2017.1329632>
- Buman, M. P., Mullane, S. L., Toledo, M. J., Rydell, S. A., Gaesser, G. A., Crespo, N. C., Pereira, M. A. (2017). An intervention to reduce sitting and increase light-intensity physical activity at work: Design and rationale of the 'Stand & Move at Work' group randomized trial. *Contemporary Clinical Trials*, 53, 11–19. <https://doi.org/http://dx.doi.org/10.1016/j.cct.2016.12.008>
- Chau, J. Y., Sukala, W., Fedel, K., Do, A., Engelen, L., Kingham, M., ... Bauman, A. E. (2016). More standing and just as productive: Effects of a sit-stand desk intervention on call center workers' sitting, standing, and productivity at work in the Opt to Stand pilot study. *Preventive Medicine Reports*, 3, 68–74. <https://doi.org/http://doi.org/10.1016/j.pmedr.2015.12.003>
- Church, T. S., Thomas, D. M., Tudor-Locke, C., Katzmarzyk, P. T., Earnest, C. P., Rodarte, R. Q., ... Bouchard, C. (2011). Trends over 5 decades in U.S. occupation-related physical activity and their associations with obesity. *PLoS One*, 6. <https://doi.org/10.1371/journal.pone.0019657>



- Cleland, I., Kikhia, B., Nugent, C., Boytsov, A., Hallberg, J., Synnes, K., ... Finlay, D. (2013). Optimal placement of accelerometers for the detection of everyday activities. *Sensors (Basel, Switzerland)*, 13(7), 9183–9200. <https://doi.org/10.3390/s130709183>
- Clemes, S. A., Houdmont, J., Munir, F., Wilson, K., Kerr, R., & Addley, K. (2016). Descriptive epidemiology of domain-specific sitting in working adults: The Stormont Study. *Journal of Public Health (United Kingdom)*, 38(1), 53–60. <https://doi.org/10.1093/pubmed/fdu114>
- Commissaris, D. a. C. M., Douwes, M., Schoenmaker, N., & de Korte, E. M. (2006). Recommendations for sufficient physical activity at work. 16th IEA World Congress on Ergonomics 2006. Meeting Diversity in Ergonomics, (Visser 2004), [http://www.tno.nl/downloads/TNO\\_KvL\\_Richtlijnen\\_vo](http://www.tno.nl/downloads/TNO_KvL_Richtlijnen_vo). Retrieved from [http://www.tno.nl/downloads/TNO\\_KvL\\_Richtlijnen\\_voldoende\\_bewegen\\_op\\_werk.pdf](http://www.tno.nl/downloads/TNO_KvL_Richtlijnen_voldoende_bewegen_op_werk.pdf)
- E. F. Graves, L., C. Murphy, R., Shepherd, S. O., Cabot, J., & Hopkins, N. D. (2015). Evaluation of sit-stand workstations in an office setting: a randomised controlled trial. *BMC Public Health*, 15(1), 1145. <https://doi.org/10.1186/s12889-015-2469-8>
- Executive, S. (2003). Let's make Scotland more active: a strategy for physical activity. Edinburgh: Scottish Executive, 35.
- Finni, T., Haakana, P., Pesola, A. J., & Pullinen, T. (2014). Exercise for fitness does not decrease the muscular inactivity time during normal daily life. *Scandinavian Journal of Medicine & Science in Sports*, 24(1), 211–219. <https://doi.org/10.1111/j.1600-0838.2012.01456.x>
- Gao, Y., Nevala, N., Cronin, N. J., & Finni, T. (2016). Effects of environmental intervention on sedentary time, musculoskeletal comfort and work ability in office workers. *European Journal of Sport Science*, 16(6), 747–754. <https://doi.org/10.1080/17461391.2015.1106590>
- Levine, J. A., & Miller, J. M. (2007). The energy expenditure of using a “walk-and-work” desk for office workers with obesity. *British Journal of Sports Medicine*, 41(9), 558–561. <https://doi.org/10.1136/bjism.2006.032755>
- McNaughton, S. A., Crawford, D., Ball, K., & Salmon, J. (2012). Understanding determinants of nutrition, physical activity and quality of life among older adults: the Wellbeing, Eating and Exercise for a Long Life (WELL) study. *Health and Quality of Life Outcomes*, 10. <https://doi.org/10.1186/1477-7525-10-109>
- Michie, S., Atkins, L., & West, R. (2015). *The behaviour change wheel: a guide to designing interventions*. 2014. ISBN-13, 978–1291846058.
- Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, 6(1), 42. <https://doi.org/10.1186/1748-5908-6-42>
- Mullane, S. L., Toledo, M. J. L., Rydell, S. A., Feltes, L. H., Vuong, B., Crespo, N. C., ... Buman, M. P. (2017). Social ecological correlates of workplace sedentary behavior. *International Journal of Behavioral Nutrition and Physical Activity*, 14(1), 117. <https://doi.org/10.1186/s12966-017-0576-x>
- Munir, F., Biddle, S. J. H., Davies, M. J., Dunstan, D., Esliger, D., Gray, L. J., ... Edwardson, C. L. (2018). Stand More at Work (SMaRT Work): Using the behaviour change wheel to develop an intervention to reduce sitting time in the workplace. *BMC Public Health*, 18(1). <https://doi.org/10.1186/s12889-018-5187-1>
- Neuhaus, M., Eakin, E. G., Straker, L., Owen, N., Dunstan, D. W., Reid, N., & Healy, G. N. (2014). Reducing occupational sedentary time: a systematic review and meta-analysis of evidence on activity-permissive workstations. *Obes Rev*, 15. <https://doi.org/10.1111/obr.12201>
- Neuhaus, M., Healy, G. N., Fjeldsoe, B. S., Lawler, S., Owen, N., Dunstan, D. W., ... Eakin, E. G. (2014). Iterative development of Stand Up Australia: A multi-component intervention to reduce workplace sitting. *International Journal of Behavioral Nutrition and Physical Activity*, 11(1). <https://doi.org/10.1186/1479-5868-11-21>
- Perchoux, C., Eaux, C., Oppert, J.-M., Menai, M., Charreire, H., Salze, P., ... Nazare, J.-A. (2017). Individual, Social, and Environmental Correlates of Active Transportation Patterns in French Women. *BioMed Research International*, 2017. <https://doi.org/10.1155/2017/9069730>

- Plotnikoff, R. C., Pickering, M. A., Flaman, L. M., & Spence, J. C. (2010). The role of self-efficacy on the relationship between the workplace environment and physical activity: A longitudinal mediation analysis. *Health Education and Behavior*, 37(2), 170–185. <https://doi.org/10.1177/1090198109332599>
- Plotnikoff, R. C., Prodaniuk, T. R., Fein, A. J., & Milton, L. (2005). Development of an ecological assessment tool for a workplace physical activity program standard. *Health Promotion Practice*, 6(4), 453–463. <https://doi.org/10.1177/1524839904263730>
- Rovniak, L. S., Denlinger, L., Duveneck, E., Sciamanna, C. N., Kong, L., Freivalds, A., & Ray, C. A. (2014). Feasibility of using a compact elliptical device to increase energy expenditure during sedentary activities. *Journal of Science and Medicine in Sport*, 17(4), 376–380. <https://doi.org/10.1016/j.jsams.2013.07.014>
- Sabia, A., & Anger Jr., W. H. (2016). Cochrane Review Brief: Workplace Interventions for Reducing Sitting at Work. *Online Journal of Issues in Nursing*, 21(1), 2. <https://doi.org/10.1002/14651858.CD010912.pub3>. Copyright
- Smith, L., Ekelund, U., & Hamer, M. (2015). The Potential Yield of Non-Exercise Physical Activity Energy Expenditure in Public Health. *Sports Medicine*, 45(4), 449–452. <https://doi.org/10.1007/s40279-015-0310-2>
- Thorp, A. A., Healy, G. N., Winkler, E., Clark, B. K., Gardiner, P. A., Owen, N., & Dunstan, D. W. (2012). Prolonged sedentary time and physical activity in workplace and non-work contexts: a cross-sectional study of office, customer service and call centre employees. *Int J Behav Nutr Phys Act*, 9. <https://doi.org/10.1186/1479-5868-9-128>
- Tudor-Locke, C., Schuna Jr., J. M., Frensham, L. J., & Proenca, M. (2014). Changing the way we work: Elevating energy expenditure with workstation alternatives. *International Journal of Obesity*, 38(6), 755–765. <https://doi.org/10.1038/ijo.2013.223>

DCE  
19

3<sup>rd</sup> DOCTORAL  
CONGRESS  
IN ENGINEERING



9 789727 522606 >