

INTEGRATED EVALUATION IN A PRODUCTION UNIT FOOD FROM THE PERSPECTIVE OF INDUSTRY 5.0

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ABSTRACT

Background: Safety, health and well-being requirements at work have reinforced the need for integrated approaches to job assessment, especially in demanding production contexts such as food preparation units. In this context, Industry 5.0 values a human-centred perspective, combining productive efficiency with the physical, cognitive and psychosocial protection of workers. **Objectives:** The present study aims to conduct an integrated assessment of a workstation in a Food Preparation Unit, focusing on the task of washing dishes with a jet, in order to identify physical, biomechanical, cognitive and psychosocial risks, as well as to substantiate proposals for improvement in line with the principles of Industry 5.0. **Methodology:** The methodology adopted is based on a multidimensional approach, utilising direct workplace observation, worker questionnaires, and recognised assessment tools for physical, cognitive, and psychosocial loads. **Results:** The results show the presence of forced postures, repetitive movements, high physical effort, time pressure, monotony and reduced autonomy, with a negative impact on the physical and emotional well-being of female workers. **Conclusions:** It can be concluded that the adoption of ergonomic, organisational and technological improvements reduces the identified risks, promoting a safer, more efficient and human-centred workplace, in accordance with the principles of Industry 5.0.

Keywords: Ergonomics, Occupational Safety, Risk Assessment, Industry 5.0.

1. INTRODUCTION

This article aims to analyse a real workstation in a Food Preparation Unit, assessing its health and safety conditions and proposing well-founded improvements. The study focuses on the task of washing dishes with a jet, an essential activity in the process of sanitising utensils in the food context, which involves significant physical, cognitive and emotional demands [29]. This task is often performed in hot and humid environments, under time pressure and with exposure to different risk factors, which makes it particularly critical from an occupational health and safety point of view [11].

The analysis focuses on the identification and integrated assessment of the risks associated with the performance of this activity, using recognised methodologies in the fields of ergonomics, safety and workload analysis. The integrated approach allows for an objective characterisation of the job, an understanding of the demands placed on the worker, and the identification of physical, biomechanical, cognitive, and psychosocial risk factors that may compromise safety, well-being, and professional performance.

In this context, and in line with the principles of Industry 5.0 the study seeks to substantiate proposals for ergonomic, organisational and technological improvements with a view to promoting a safer, more efficient and human-centred working environment [2].

2. MATERIALS AND METHODS

The study takes the form of a case study focused on the integrated assessment of the workstation under analysis, specifically the task of washing dishes with a jet. The adopted methodology is based on a multidimensional approach that integrates the analysis of physical, cognitive, and psychosocial risks, allowing for the characterisation of the demands placed on the worker and the conditions under which the task is performed.

The selection of the workplace considered its relevance in the utensil sanitising process within the food context and the characteristics of the thermal environment. The activity takes place in a hot and humid space, with contact with hot water, steam, and bulky, slippery utensils, involving repetitive movements of the upper limbs, prolonged standing, and adaptation to the pace of work. The workstation is integrated into a space shared with other unit operations, conditioning the reaches, the adopted postures, and the organisation of the workflow.

The assessment of physical well-being was carried out using recognized methodologies in the field of ergonomics and occupational risk prevention. The manual handling of loads associated with the transport of trays and pans was analysed using the National Institute for Occupational Safety and Health (NIOSH) equation, allowing the biomechanical effort associated with the transport of heavy trays and pans to be quantified and determining the recommended weight limits to prevent spinal injuries [28]. Physical and mechanical risks, namely the risk of wet loads falling and the risk of burns, were assessed using the 5×5 Matrix, selected to prioritize interventions based on the probability and severity of non-ergonomic risks, such as burns. The overall postural analysis of the body was performed using the Rapid Entire Body Assessment (REBA) method [13], while localized and repetitive stress on the upper limbs, particularly the wrists and forearms, was assessed using the Rapid Upper Limb Assessment (RULA) method, focusing on the musculoskeletal load caused by the continuous use of the water jet [18]. In addition, the Nordic Musculoskeletal Questionnaire (NMQ) was applied to identify the presence of musculoskeletal complaints and discomfort associated with work activity [17].

Regarding cognitive well-being, the assessment focused on the mental workload of the task, considering visual-motor coordination, the repetitiveness of actions, and time pressure during periods of high demand. To this end, cognitive workload analysis tools were used, namely the National Aeronautics and Space Administration Task Load Index (NASA-TLX) [12] to assess subjective perception of effort, and the Subjective Workload Assessment Technique (SWAT) [22] selected for its high sensitivity to the time pressure and stress of food production units. Additionally the Goals, Operators, Methods, and Selection rules (GOMS) model [1], and the Systematic Human Error Reduction and Prediction Approach (SHERPA) [8], were used to map task structure and anticipate potential operational failures.

The assessment of emotional and psychosocial well-being was conducted using recognized instruments for analysing occupational stress and psychosocial conditions at work. The Health and Safety Executive Management Standards (HSE) [7], the Copenhagen Psychosocial Questionnaire (COPSOQ) [16], the Job Content Questionnaire (JCQ) [14], the Effort-Reward Imbalance (ERI) model [25], and the World Health Organization Five Well-Being Index (WHO-5) [27] were used, enabling the analysis of dimensions such as job demands, level of autonomy, social support, balance between effort and reward, and the worker's overall emotional well-being.

The selection of instruments was justified by their validation in the literature and suitability for assessing physical, cognitive, and psychosocial demands in the food sector. The assessment process included direct observation on-site during one working day, accompanying one worker, out of a total of four who perform the task (51 years of age; 20 years of experience in the role). The data collection protocol took place during the normal shift, cross-referencing questionnaire responses, show in Annex C, with observational evidence to ensure the reliability and validity of the information.

3. RESULTS

The risk assessment was carried out based on three dimensions: physical, cognitive, and psychosocial. This approach makes it possible to identify factors that may affect workers' health and performance, providing a basis for the implementation of improvements in the working environment. The integration of these dimensions facilitates a comprehensive analysis of workstation conditions and contributes to the promotion of a safer and more efficient environment [24].

3.1. RISK IDENTIFICATION

To carry out the assessment of risks associated with the work performed in the kitchen, the analysis focused exclusively on the tasks directly observed on site, complementing the evidence collected through observation with the responses provided in the questionnaire applied to the worker.

Figure 1 illustrates the operation of washing dishes using a spray jet, allowing the identification of the associated risks.



Figure 1: Process: Wash the dishes with a jet

Process description:

- 1) The worker collects the dirty dishes and places them near the dishwashing area
- 2) She removes food residues using repetitive scrubbing movements.
- 3) She uses the water spray jet, which requires constant pressure on the trigger mechanism.
- 4) She significantly bends her trunk to reach the bottom of the sink.
- 5) She alternates trunk positions between the washing, rinsing, and draining areas.
- 6) She handles wet and slippery pots and trays.
- 7) It was observed that she did not use protective gloves, increasing skin exposure to chemical agents.

The analysis of the dishwashing task revealed the presence of multiple risk typologies. In the mechanical domain, there is a susceptibility to cuts during the handling of sharp utensils or those with damaged edges. From a biomechanical perspective, the execution of the task requires trunk flexion, conditioned by the depth of the sink, and repetitive movements of the arms and wrists. The activity entails prolonged standing, the adoption of asymmetrical postures when handling heavy pots, and the transport of wet and slippery loads.

Regarding physical factors, there is contact with hot water and exposure to humidity and steam. Simultaneously, the ergonomic assessment reveals constraints arising from the limited space between the washing, draining, and storage areas. The thermal environment exacerbates postural discomfort, while the slippery flooring imposes compensatory postural adjustments during the execution of the activity.

Concerning chemical risks, there is contact with detergents and degreasers. The absence of protective gloves increases the risk of dermatitis, skin irritation, and the absorption of substances, a situation exacerbated by the inhalation of cleaning product vapours in the hot and humid environment.

3.2. RESULTS OF THE ANALYSIS OF PHYSICAL WELL-BEING

The assessment of physical risks was conducted using recognized methodologies, as detailed in Table 5 in Annex A. The transport of trays and pots, which involves lifting and carrying loads, was analysed using the NIOSH'91 Equation, allowing the quantification of biomechanical effort. The risk of dropping wet loads was analysed using the 5×5 Matrix, considering its sudden impact. Postures adopted during the operation of placing dishes in the sink area were assessed using the REBA method, which evaluates overall body posture. Burns associated with the use of the washing spray jet were assessed using the 5×5 Matrix, and repetitive demands on the wrists and forearms were analysed using the RULA method, due to localized and repetitive effort.

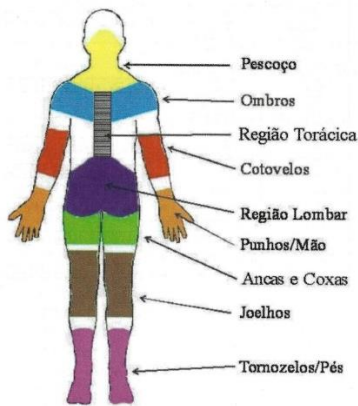
3.2.1. NORDIC QUESTIONNAIRE

The Nordic Musculoskeletal Questionnaire is a widely used instrument for identifying and analysing the occurrence of musculoskeletal pain and discomfort in different populations, particularly in work environments. Developed in the Nordic countries, it is a standardized questionnaire that helps detect problems in various body regions and assess possible relationships with working conditions, thereby supporting the adoption of ergonomic improvements [23]. The version of the Nordic Musculoskeletal Questionnaire used in this study is presented in Figure 2. Its structure includes questions about the onset of symptoms in areas such as the neck, shoulders, back, and limbs, considering specific periods, such as the last 7 days or the last 12 months. The questionnaire also evaluates whether these symptoms interfere with daily routines or professional activities, providing a clear view of the impact of musculoskeletal complaints on workers' lives.

Questionário Nórdico Músculo-esquelético

Instruções para o preenchimento

- Por favor, responda a cada questão assinalando um "X" na caixa apropriada: ☐
- Marque apenas um "X" por cada questão.
- Não deixe nenhuma questão em branco, mesmo se não tiver nenhum problema em qualquer parte do corpo.
- Para responder, considere as regiões do corpo conforme ilustra a figura abaixo.



Considerando os últimos 12 meses, teve algum problema (tal como dor, desconforto ou dormência) nas seguintes regiões:		Responda, apenas, se tiver algum problema	
		Teve algum problema nos últimos 7 dias, nas seguintes regiões:	Durante os últimos 12 meses teve que entrar as suas actividades normais (trabalho, serviço doméstico ou passeios) por causa do problema nas seguintes regiões:
1. Pescoço?	Não ☐ Sim ☐	2. Pescoço?	Não ☐ Sim ☐
5. Ombros?	Não ☐ Sim ☐	6. Ombros?	Não ☐ Sim ☐
9. Cotovelo?	Não ☐ Sim ☐	10. Cotovelo?	Não ☐ Sim ☐
13. Punho/Mão?	Não ☐ Sim ☐	14. Punho/Mão?	Não ☐ Sim ☐
17. Região Torácica?	Não ☐ Sim ☐	18. Região Torácica?	Não ☐ Sim ☐
21. Região Lombar?	Não ☐ Sim ☐	22. Região Lombar?	Não ☐ Sim ☐
25. Ancas/Coxas?	Não ☐ Sim ☐	26. Ancas/Coxas?	Não ☐ Sim ☐
29. Joelhos?	Não ☐ Sim ☐	30. Joelhos?	Não ☐ Sim ☐
33. Tornozelos/Pés?	Não ☐ Sim ☐	34. Tornozelos/Pés?	Não ☐ Sim ☐

Figure 2: Nordic Musculoskeletal Questionnaire

3.2.2. NIOSH'91 EQUATION

In this method, a maximum recommended weight, referred to as the load constant (LC), is considered to be 23 kg, to which various adjustment factors (multipliers) are applied, as shown in the following equations, depending on the deviations present in the task under study in relation to the optimal conditions [10]. The NIOSH'91 equation is presented in Equation 1.

Equation 1- NIOSH '91 Equation

$$RWL = LC \times HM \times VM \times DM \times AM \times GM \times FM \text{ (Kg)}$$

For the application of the NIOSH'91 Equation, the specific characteristics of tray handling were considered, including the movement of removing the trays from the tray rack and transporting them to the dishwashing area. This equation is used to calculate the effort associated with manual load lifting and is based on the parameters presented in table 1.

Table 1: Elevation Characteristics

Features	
H	30 cm
V	180 cm
D	220 cm
A	90 °
W	4 cm

For the calculation of each multiplier within the aforementioned NIOSH'91 Equation, the specific elevation parameters and characteristics detailed in table 1 shall be applied as defined by the following formulations:

Equation 2 - Horizontal Multiplier

$HM = \frac{25}{H}$, where H is the horizontal distance at the start of the elevation.

Equation 3 - Vertical Multiplier

$VM = 1 - (0.003) \times |V - 75|$, where V is the height at which the lift begins.

Equation 4 - Distance Multiplier

$DM = 0.82 + \frac{4.5}{D}$, where D is the vertical distance between the starting point and the end point of the elevation.

Equation 5 - Asymmetry Multiplier

$AM = 1 - (0.0032 \times A)$, where A is the angle of rotation of the trunk during the lift.

Equation 6 - Grip Multiplier

GM – Value dependent on the quality of the handle, determined from Table 6 of Annex A.

Equation 7 - Frequency Multiplier

FM – Value dependent on the frequency of elevations, determined from Table 8 of Annex A.

Equation 8 - Horizontal Distance

$H = 20 + \frac{W}{2}$, where W is the dimension corresponding to the depth of the object and is used to determine the value of H when $V \geq 25$ cm.

Table 2 presents the calculated values for the various multipliers, which will be applied to the NIOSH equation to obtain the Recommended Weight Limit (RWL).

Table 2: Multipliers and RWL

Multipliers	
HM	0.83
VM	0.685
DM	0.84
AM	0.712
GM	1
FM	0.42
RWL	3.28 Kg

In situations where the actual weight of the objects exceeds the Recommended Weight Limit (RWL) and it is not possible to reduce the weight or use mechanical assist devices, it is necessary to establish an absolute upper limit, the Lifting Index (LI), as presented in Equation 9, to ensure a minimum level of protection for the worker, with such circumstances being considered exceptional [10].

Equation 9 - Lifting Index

$$LI = \frac{L}{RWL}, \text{ where } L = 1.426 \text{ Kg is the actual weight of the object}$$

Risk assessment using the NIOSH'91 Equation is interpreted based on the Lifting Index (LI). According to the criteria of this method, an LI value greater than 3 is considered unacceptable. Results between 1 and 3 indicate a risk of musculoskeletal injury, requiring the implementation of corrective measures. Conversely, an index below 1 denotes the absence of significant risk [5]. In the present case, the calculated Lifting Index was 0.4347, leading to the conclusion that the manual load handling task poses no associated risk to the worker.

3.2.3. 5×5 MATRIX

The risk assessment was carried out using the 5×5 Matrix, which classifies risks based on the probability of occurrence and the severity of their consequences, and is duly presented in Table 9 of Annex A. The main risks identified were the risk of dropping wet and slippery loads and the risk of burns, as shown in Table 3.

Table 3: Results of the 5×5 Matrix Assessment

Risk	Frequency	Severity	F × G	Level
Falling wet and slippery loads	4	2	8	Moderate
Burns	3	4	12	High

The risk of dropping wet and slippery loads was classified with a frequency of 4 (likely) and a severity of 2 (minor), resulting in an F × G score of 8, which places it at a moderate level.

The risk of burns was classified with a frequency of 3 (possible) and a severity of 4 (severe), resulting in an F × G score of 12, placing it at a high level.

3.2.4. REBA

The REBA assessment indicated a very high risk for the task of placing dishes in the sink area, with a final score of 11 points, as shown in Figure 3.

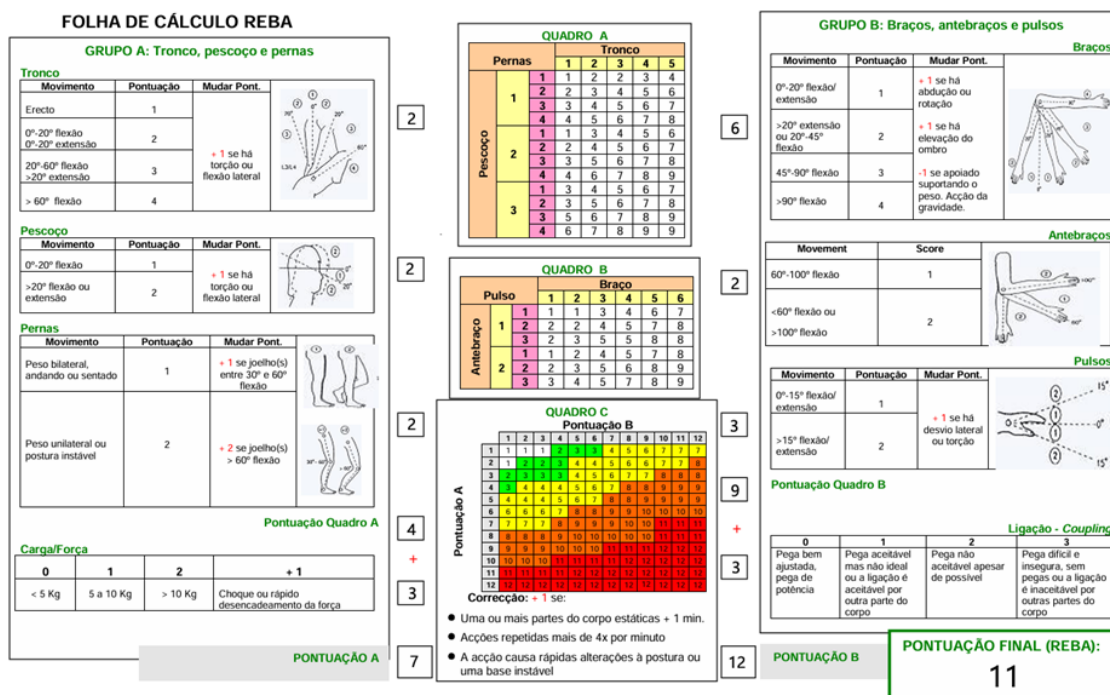


Figure 3: Evaluation of Results Obtained Using the REBA Method

The trunk is maintained in a flexion of 0° to 20° (2 points), and the neck is flexed above 20° (2 points). The legs show bilateral support with slight knee flexion (2 points), resulting in a total of 4 points in Section A.

The weight of the dishes and the effort required to stabilize slippery items resulted in an additional 3 points in Section A, bringing the total to 7 points. The upper arm reaches flexion above 90° (6 points), the forearm bends between 60° and 100° (2 points), and the wrist shows flexion/extension greater than 15° with lateral deviation/twisting (1 point), totaling 9 points in Section B. The grip was considered poor due to the wet dishes, adding 3 points.

3.2.5. RULA

The assessment of the right upper limb, shown in Figure 4, focuses on the postures and movements adopted during the task, as this limb is responsible for handling and coordinating the water jet, in addition to holding and adjusting the dish [15]. The combination of continuous movements and repetitive postures requires a detailed analysis, particularly considering biomechanical loads and the risk of musculoskeletal injuries.

- **Arm:** Flexion between 20° and 40°, adjusting the jet and repositioning the dish, especially when it is larger or slippery.
- **Forearm:** Maintains flexion between 80° and 100°, allowing control of the jet and elbow stability.
- **Wrist:** Moderate flexion of 10° to 15°, with radial or ulnar deviation to adjust the trajectory of the water.

The task also involves repetitive movements to reposition the jet and adjust the dish. The neck maintains flexion between 10° and 20° to ensure visibility of the dish, while the trunk presents slight flexion (5° to 10°) to compensate for the depth of the sink. The posture of the lower limbs is stable, with slight weight transfer to the right side to ensure balance.

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RULA – RAPID UPPER LIMB ASSESSMENT

Folha de Avaliação de um Posto de Trabalho, Adaptado de Proformix, RULA Employee Assessment Worksheet

A. ANÁLISE DO MEMBRO SUPERIOR E PULSO

Passo 1: Verificar posição do Braço

Passo 1a: Ajuste
 Caso o ombro esteja levantado: +1
 Caso haja abdução do braço: +1
 Caso os ombros estejam apertados: -1

Ponto final do Braço = 4

Passo 2: Verificar posição do antebraço

Passo 2a: Ajuste
 Caso o antebraço se cruze com a linha central do corpo ou trabalhe na parte lateral: +1

Ponto final do Antebraço = 3

Passo 3: Verificar posição do pulso

Passo 3a: Ajuste
 Caso o pulso esteja flexionado lateralmente (abdução ou adução): +1

Ponto final do Pulso = 3

Passo 4: Rotação do pulso
 Caso haja flexão rotatória: +1
 Caso haja rotação do pulso até próximo do limite: +2

Ponto final de Rotação do Pulso = 2

Passo 5: Cálculo da pontuação para a postura na Tabela A
 Utilize os valores dos passos 1 a 4 para encontrar a pontuação para a postura na tabela A

Ponto A = 5

Passo 6: Adicione a pontuação da Utilização Muscular
 Caso a postura seja essencialmente estática: +1
 Caso a postura seja mantida por mais de 1 min ou repetida por mais de 4 x por min: +1

Ponto de Utilização Muscular = 1

Passo 7: Adicionar pontuação da Carga/Força
 Sem carga ou carga inferior a 2 Kg (intermitente): +0
 Força ou carga de 2 a 10 Kg (intermitente): +1
 Força ou carga de 2 a 10 Kg (estática ou repetitiva): +2
 Força ou carga com mais de 10 Kg, choques ou aplicação de força de forma repetitiva: +3

Ponto de Carga/Força = 3

Passo 8: Determinar a linha da tabela C
 A pontuação completa da análise do membro superior/pulso é utilizada para determinar a linha na tabela C

Ponto final do Pulso e Membro Superior = 9

B. ANÁLISE DO PESCOÇO, TRONCO e MEMBROS INFERIORES

Passo 9: Verificar posição do pescoço

Ponto final do Pescoço = 3

Passo 9a: Ajuste
 Caso haja rotação lateral do pescoço: +1
 Caso haja inclinação lateral do pescoço: +1

Passo 10: Verificar posição do tronco

Passo 10a: Ajuste
 Caso haja inclinação lateral do tronco: +1

Ponto final do Tronco = 2

Passo 11: Pernas
 Pernas e pés bem apoiados e em postura bem equilibrada: +1
 Pernas e pés mal apoiados e em postura instável: -2

Ponto final das Pernas = 1

Tabela A

Braço	Antebraço	Pulso			
		1	2	3	4
1	1	1	2	1	2
2	2	2	2	2	3
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9

Tabela B

Pescoço	Tronco					
	1	2	3	4	5	6
1	1	2	1	2	1	2
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6

Tabela C

	1	2	3	4	5	6	7	8	9
1	1	2	3	4	5	6	7	8	9
2	2	3	4	5	6	7	8	9	10
3	3	4	5	6	7	8	9	10	11
4	4	5	6	7	8	9	10	11	12
5	5	6	7	8	9	10	11	12	13
6	6	7	8	9	10	11	12	13	14
7	7	8	9	10	11	12	13	14	15
8	8	9	10	11	12	13	14	15	16
9	9	10	11	12	13	14	15	16	17

Ponto final da Pontuação Final = 7

Passo 12: Cálculo da pontuação para a postura na Tabela B
 Utilize os valores dos passos 8 a 10 para encontrar a pontuação para a postura na tabela B

Ponto B = 2

Passo 13: Adicione a pontuação da Utilização Muscular
 Caso a postura seja essencialmente estática: +1
 Caso a postura seja mantida por mais de 1 min ou repetida por mais de 4 x por min: +1

Ponto de Utilização Muscular = 1

Passo 14: Adicionar pontuação da Carga/Força
 Sem carga ou carga inferior a 2 Kg (intermitente): +0
 Força ou carga de 2 a 10 Kg (intermitente): +1
 Força ou carga de 2 a 10 Kg (estática ou repetitiva): +2
 Força ou carga com mais de 10 Kg, choques ou aplicação de força de forma repetitiva: +3

Ponto de Carga/Força = 3

Passo 15: Determinar a coluna da tabela C
 A pontuação completa da análise do pescoço, membros inferiores e tronco é utilizada para determinar a coluna na tabela C

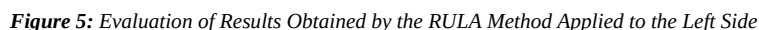
Ponto final do Pescoço, Tronco e Membro Inferior = 5

Figure 4: Evaluation of Results Obtained by the RULA Method Applied to the Right Side

The assessment of the left upper limb, shown in Figure 5, focuses on the postures and movements adopted during the task, as this limb plays a support role, providing stabilization and adjustment of the dish while the right limb controls the water jet. Although it is not primarily responsible for manipulating the jet, this limb also presents significant biomechanical demands.

- **Arm:** Flexion between 10° and 25°, adjusting according to the position and weight of the dish. The limb requires continuous muscle activation to stabilize utensils during the operation.
- **Forearm:** Maintains flexion between 70° and 100°, necessary to hold and rotate the dish, bringing it closer to the washing area.
- **Wrist:** Slight flexion between 5° and 15°, with occasional deviations to adjust the position of the dish, compensating for instability caused by water.

The task also involves repetitive movements to rotate the dish, stabilize it, and adjust its position. The neck maintains flexion between 10° and 20° to ensure constant visibility of the dish. The trunk presents slight flexion (5° to 10°) and occasional rotation to reposition the dish within the impact area of the jet. The posture of the lower limbs is stable, with adjustments of the left foot to facilitate reach and stabilization of the dish.



The task requires a high mental workload due to repetition and the need for constant precision, in addition to managing time pressure during peak work periods. Visual–motor coordination is essential, particularly when handling the water jet, and error prevention is crucial to avoid splashing and burns.

- **NASA-TLX:** Analysed mental, physical, and temporal effort, identifying an increase in cognitive workload due to jet control and the coordination required [4].
- **GOMS:** Action decomposition, highlighting potential errors such as delayed jet adjustments or incorrect positioning of the dish.
- **SWAT:** Assessed how time pressure and continuous effort increase cognitive stress, especially during periods of high demand [4].
- **SHERPA:** Identified potential failures, such as incorrect utensil selection or changes in the washing sequence.

The NASA-TLX assessment grid, shown in Figure 6, was completed to measure perceived workload.

NASA TLX

Referências: Hart, S.G. & Staveland, L. E. Development of NASA TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock and N. Meshkati. Human Mental Workload. Amsterdam: North Holland Press, 1988.

Demanda	Crîtérios
1. Demanda mental (MD)	Quanto de atividade mental e de percepção foi exigido pela tarefa? Essa demanda está relacionada às atividades de pensar, raciocinar, perceber, decidir, calcular, lembrar, procurar e pesquisar. A tarefa foi fácil ou difícil, simples ou complexa, de alta ou baixa exigência?
2. Demanda física (PD)	Quanto de atividade física foi exigido? Essa demanda está relacionada a esforços como empurrar, puxar, girar, controlar e ativar. Também inclui as exigências de calor, frio e vibração. A tarefa foi fácil ou difícil, rápida e estimulante ou devagar e cansativa, vigorosa ou lenta, de alta ou baixa exigência?
3. Demanda temporal (TD)	Quanto de pressão de tempo foi imposto para se conseguir o resultado em razão do ritmo de trabalho imposto? Também inclui avaliação do ritmo de trabalho: lento, normal ou rápido?
4. Performance (OP)	Houve êxito ao realizar o trabalho? Quanto ficou satisfeito com o seu próprio desempenho no trabalho? Essa demanda está relacionada à realização do objetivo (pessoal ou profissional).
5. Esforço/ Empenho (EF)	Quanto de esforço (físico ou mental) foi necessário para conseguir o resultado do trabalho? Essa demanda é relativa à carga de trabalho e à necessidade de empenho para conseguir o resultado.
6. Frustração (FR)	Quanto de insegurança, desânimo, irritação, de estresse ou aborrecimento o indivíduo teve ao longo da jornada de trabalho? Essa demanda está relacionada com os sentimentos de insegurança, desânimo e irritação ao realizar a atividade.

1. Comparação de escalas: Escolha, entre cada par de escalas, a exigência predominante no trabalho:			
1. Demanda mental X Demanda física	PD	9. Performance X Frustração	FR
2. Demanda temporal X Demanda física	TD	10. Frustração X Demanda mental	FR
3. Demanda temporal X Frustração	TD	11. Esforço X Demanda física	EF
4. Demanda temporal X Demanda mental	TD	12. Performance X Esforço	EF
5. Performance X Demanda física	PD	13. Esforço X Demanda mental	EF
6. Demanda temporal X Esforço	TD	14. Demanda temporal X Performance	TD
7. Performance X Demanda mental	MD	15. Esforço X Frustração	EF
8. Nível de frustração X Demanda física	PD		

2. Classificação: Em cada fator, selecione qual escala representa a exigência/ intensidade em relação ao seu trabalho:														
1. Demanda mental (MD)	Baixa	0	10	20	30	40	50	60	70	80	90	100	Alta	40
2. Demanda física (PD)	Baixa	0	10	20	30	40	50	60	70	80	90	100	Alta	80
3. Demanda temporal (TD)	Baixa	0	10	20	30	40	50	60	70	80	90	100	Alta	90
4. Performance (OP)	Excelente	0	10	20	30	40	50	60	70	80	90	100	Ruim	30
5. Esforço/ Empenho (EF)	Baixo	0	10	20	30	40	50	60	70	80	90	100	Alto	80
6. Frustração (FR)	Baixa	0	10	20	30	40	50	60	70	80	90	100	Alta	50

3. Resultados:				
Fator	Nº de vezes assinalado - Item 1 [Peso]	Classificação na escala - Item 2 [Taxa]	Ajuste [Peso X Taxa]	Índice de carga individual [Ajuste/15]
1. Demanda mental (MD)	1	40	40	2,7
2. Demanda física (PD)	3	80	240	16
3. Demanda temporal (TD)	5	90	450	30
4. Performance (OP)	0	30	0	0
5. Esforço/ Empenho (EF)	4	80	320	21,3
6. Frustração (FR)	2	50	100	6,7
Soma dos índices de carga:			76,7	
ÍNDICE DE CARGA GLOBAL (soma dos índices individuais/15):			5,1	

Adaptado por Higor Martins Eleutério. Ergonomista Certificado pela ABERGO (SisCEB 128/2010).

Figure 6: Evaluation of Results Obtained Using the NASA-TLX Tool

The overall index of 5.1 indicates a moderate workload, with a high temporal demand, where the main source of strain is the fast work pace and the need to prevent the accumulation of trays.

Physical demand is high, generating muscular fatigue due to the continuous handling of the water jet and heavy utensils. Mental demand is low, focusing mainly on avoiding splashing and ensuring effective cleaning. Performance does not generate significant pressure, and frustration is moderate, associated with heat, humidity, and noise.

In summary, the task is physically demanding, with strong temporal pressure but low cognitive complexity.

3.3.2. SWAT

The application of the SWAT methodology to the task revealed the following results:

- **Time (T): High level**

The task is highly constrained by the fast pace of the kitchen and dishwashing area. The worker must maintain a constant workflow to avoid the accumulation of utensils, with short response times, especially during peak periods.

- **Stress (S): Medium to High level**

The work environment is demanding, with heat, high humidity, intense noise, and constant splashing. The pressure to correctly direct the water jet and avoid burns or accidents increases emotional strain, particularly during peak workload periods.

- **Effort (E): High level**

Physical effort is significant due to the continuous handling of the pressure jet, the transport of heavy utensils, and prolonged standing work. Muscular load accumulates throughout the shift, especially during periods of high utensil flow.

The combination of temporal pressure, physical effort, and stress results in a high workload, where speed and physical endurance are essential for task performance.

3.3.3. SHERPA

The application of the SHERPA method, presented in Table 4, identified frequent human errors, such as incorrect actions and inappropriate decisions, caused by time pressure, fatigue, humidity, and tray instability. The consequences include dish dropping, splashing, burns, and rework.

The proposed measures include ergonomic improvements, standardization of methods, visual signage, and adjustments to the layout and equipment, aiming to reduce errors and improve safety [20].

Table 4: Evaluation of Results Obtained by the SHERPA Tool

Task step	Type of error	Error description	Consequence	Probable cause	Preventive measures
Remove trays from the tray holder	Action error	Holding the tray in an unstable manner or tilting it too much	Falling tray; splashes; risk of burns from hot dishes; breakages	Wet and slippery trays; rushing; improper grip; limited torso position	Improve support area; optimise height of supports; introduce non-slip handles; training on safe handling
Transporting trays to the kitchen area	Sequence error	Transporting several trays simultaneously, compromising stability	Falling crockery; increased risk of injury; contamination	Excessive load; attempt to speed up the process; cramped space	Limit the number of trays per transport; reorganise layout; create visual instructions
Use the pressurised water jet	Action error	Directing the jet to the wrong area or too close to the operator	Splashes; risk of burns; excessive moisture in the workstation; increased effort	High water pressure; arm fatigue; unstable grip; conditioned reflexes	Adjust jet pressure; provide instructions on safe distance; improve grip ergonomics
Place heavy crockery under the jet	Decision error	Choosing poor positioning, requiring postural compensation	Increased joint strain; risk of dropping dishes; reduced efficiency	Inappropriate counter height; partial vision due to steam; visual fatigue	Adjust canopy height; improve lighting; support brackets for heavy crockery
Remove stubborn dirt with a targeted jet	Recovery error	Do not immediately correct pressure or angle errors	Rework; prolonged exposure to the jet; increased fatigue	Repetitive movements; lack of tactile feedback; rushing	Technique training; short scheduled breaks; ergonomic feedback jet
Place washed dishes in the kitchen to drain	Error of omission	Failure to ensure that crockery is properly placed and stable	Dish breakage; contamination; rework	Limited space; overloaded cupboards; rush to free up space	Redesign of the pantry; delimitation of zones; review of available capacity

3.3.4. GOMS

The application of the GOMS method revealed the following points:

- **Goals:** Assess dirt, adjust the jet, remove residues, and transfer the dishes to the dishwashing area.
- **Operators:** The task requires continuous attention, manual coordination, and postural control.
- **Method:** The sequence involves adjusting the jet, applying it, repositioning the dish, and transporting it to the dishwashing area.
- **Selection Rules:** The worker adapts to the environment by adjusting jet force, stabilizing lightweight utensils, and prioritizing larger items in cases of accumulation.

3.4. RESULTS OF THE ANALYSIS OF EMOTIONAL AND PSYCHOSOCIAL WELL-BEING

Emotional and psychosocial well-being refers to the worker's psychological state, including stress, mental fatigue, and motivation. In this activity, time pressure and low autonomy are exacerbated by task repetitiveness and a fast work pace. The work environment, characterized by noise, heat, and steam, contributes to emotional wear and overload. The lack of structured breaks increases monotony.

The assessment was conducted using the following tools:

- **HSE Standards:** Noise and pressure increase stress levels.
- **OPSOQ:** Identified monotony and fatigue.
- **JCQ:** Low autonomy increases stress.
- **ERI:** Effort is not adequately rewarded, leading to feelings of undervaluation.
- **WHO-5:** Heat and noise reduce well-being and vitality.

3.4.1. HSE STANDARDS

The analysis of emotional and psychosocial well-being focused on how physical and environmental demands affect the worker's mental health and well-being during the task, identifying sources of stress and psychological overload [3].

The task presents high physical and mental demands, with low control and strong time pressure. Regarding demands, the task imposes continuous handling of the water jet (physical), constant attention to avoid burns (mental), and pressure due to dish accumulation (emotional). Control is minimal, with the pace dictated by the workflow and lacking natural breaks. Support is limited to informal peer assistance, without an organisational structure. Relationships are cooperative but tense during peak periods. The worker's role is clear, albeit with a perception of overload. Finally, frequent change in the layout and workflow exacerbates the mental workload, highlighting the need for organisational improvements.

The analysis indicates that organizational improvements are necessary to reduce emotional and psychological load.

3.4.2. COPSOQ

The application of the COPSOQ identified a high psychosocial risk. Regarding work demands, the task imposes cognitive load through constant attention, emotional strain associated with a sense of urgency in an adverse environment, and fatigue resulting from continuous and repetitive movements. In terms of work organisation and social relations, autonomy is reduced by the flow of trays, and support is strictly informal, lacking structured breaks. Relationships remain positive, manifesting tensions during peak service periods. Concerning values, justice, and leadership, there is a lack of recognition, unequal task distribution, and reactive communication from management, resulting in the perception that the role, although essential, is undervalued.

3.4.3. JCQ

The task of washing dishes using the water jet presents high demands and low control, configuring a "job strain" scenario.

Regarding job demands, the intense physical effort due to the continuous handling of the water jet and thermal exposure is combined with pace-related pressure to prevent dish accumulation, as well as the emotional strain of constant vigilance against burns and splashes. Decision latitude is

reduced, with the worker having little autonomy over the organisation and pace of the task. With limited organisational social support, restricted to informal peer assistance and few structured breaks, this combination exacerbates stress and fatigue, highlighting the need for improvements in work control and organisation.

3.4.4. ERI

The analysis using the ERI model revealed a significant imbalance between the effort expended and the reward obtained. Regarding effort, the continuous handling of the water jet, exposure to heat, steam, and humidity, as well as the moving of heavy dishes, represent an intense physical load. To this is added the cognitive demand of constant attention to dirt and water flow, exacerbated during peak service periods. In terms of reward, there is limited formal recognition given the essential nature of the task, support restricted to informal peer assistance without a supporting organisational structure, and the presence of burn risks without adequate safety measures. This disproportion culminates in a clear imbalance, where the worker's commitment is not compensated by adequate recognition or support, generating negative emotional consequences where the perception of injustice exacerbates stress and fatigue.

4. DISCUSSION

4.1. DISCUSSION OF RESULTS

The integrated assessment of the dishwashing workstation reveals a high level of risk across multiple dimensions, highlighting the urgent need for intervention under the Industry 5.0 framework. The convergence of results from various methods provides a holistic view of the worker's burden, where physical strain is exacerbated by cognitive pressure and psychosocial imbalances.

In the physical domain, the results of the NIOSH'91 Equation present a Lifting Index (LI) of 0.4347, situating it below the safety threshold of 1.0. This indicates that the weight of the trays and pots does not, in itself, represent a direct risk of lumbar injury. However, the 5×5 Matrix identifies that the environmental context is critical: the risk of burns ($F \times G = 12$) was classified as "High", requiring immediate action due to contact with steam and hot water, while the dropping of wet and slippery loads ($F \times G = 8$) presents a "Moderate" risk, exacerbated by frequently wet floors. It is necessary to plan preventive actions to minimize the likelihood of falls, especially in environments with slippery floors due to water or other liquids [21]. This environmental hazard is directly reflected in posture and physical exertion. The REBA (11) and RULA (7) scores indicate the need for immediate intervention, highlighting that the inadequate height of the sink and the force required to operate the jet spray force the worker into extreme postures of trunk flexion and repetitive effort [19]. The analysis of working conditions suggests that the organisation of space is essential to minimise this impact, a finding validated by the Nordic Questionnaire, where the reported symptomatology confirms that physical demands are outstripping recovery capacity.

This physical risk does not occur in isolation, being fuelled by a strong mental component. The NASA-TLX revealed an overall index of 5.1 (moderate load), but with a high "temporal demand"; the fast pace to prevent the accumulation of trays is the primary source of stress. The SWAT method reinforces this conclusion, demonstrating that the combination of time pressure, physical effort, and stress results in a high workload. The application of the GOMS and SHERPA models allowed for the perception that, although the task has low cognitive complexity, its repetitive

structure induces error. Ergonomic improvements and the standardisation of methods could reduce this cognitive load and improve process fluidity.

From a psychosocial and organisational perspective, the HSE Standards, JCQ, and ERI analyses converge towards a "High Strain" scenario. The combination of high demands with low control and moderate social support significantly increases fatigue. The imbalance between the effort expended and organisational rewards, measured by the ERI and reflected in the WHO-5, compromises the worker's emotional well-being, opposing the principles of Industry 5.0.

To align this workstation with Industry 5.0, the discussion must focus not on the weight of loads (since the LI is 0.4347), but rather on ergonomic design and technological integration. Improvements such as height-adjustable sinks are essential to reduce REBA/RULA indices. Concurrently, collaborative systems or automatic jet stabilisers should be explored to reduce cognitive load and temporal pressure.

4.2. COMPARISON OF RESULTS WITH SIMILAR STUDIES

The analysis developed in this article is consistent with previous studies on manual dishwashing tasks in food service settings. Chim (2006), in the study "*Ergonomics workload analysis for the prevention of musculoskeletal disorders in food services in the health sector*", identified manual dishwashing as one of the tasks with the highest physical demands and greatest perceived effort when compared to other activities performed in industrial kitchens. The study highlighted the presence of repetitive movements, sustained postures, prolonged standing, and a high work pace—factors associated with an increased risk of musculoskeletal disorders [6].

Similarly, the present study demonstrates that dishwashing using a spray gun also involves high biomechanical and psychosocial workload, as confirmed by postural assessments and the identified time pressure. Although Chim (2006) focused on conventional manual dishwashing, there is clear convergence regarding the nature of the associated risks.

However, the use of a spray gun introduces additional demands related to prolonged equipment gripping, jet control, and the risk of splashing and burns. Thus, this article provides a more in-depth analysis of a specific variant of the dishwashing task, reinforcing the need for ergonomic and organizational interventions aligned with the principles of Industry 5.0. Table 11, included in Annex D, summarizes the comparison between both studies.

4.3. IDENTIFICATION OF OPPORTUNITIES AND CONSTRUCTION OF THE TO-BE SCENARIO (INDUSTRY 5.0)

The analysis of the task "Dishwashing using a water jet" revealed significant biomechanical, cognitive, and emotional risks. The application of the RULA method assigned a score of 7 to both sides of the body, indicating a high-risk level and the need for immediate intervention [9]. The observed postures include repeated neck and trunk flexion, arm elevation and abduction, prolonged gripping of the water jet, and frequent wrist rotations. The NIOSH Equation highlighted high physical effort associated with handling pots and trays, while the 5×5 Risk Matrix identified relevant risks related to the dropping of wet objects and burns.

In parallel, cognitive workload was found to be high, reflecting the need to simultaneously control the water jet, dish positioning, and work pace. Time pressure and task monotony further contribute to emotional strain, as indicated by the SWAT, ERI, and WHO-5 methods.

The synthesis of the results obtained, and the estimated benefits associated with the implementation of improvement measures are systematized in Table 10 of Annex B. This table

presents a comparison between the As-Is scenario, corresponding to the current situation of the workstation prior to intervention, and the To-Be scenario, which reflects the estimated future condition after the implementation of the proposed improvements, as well as the expected impacts on the worker's health, safety, and well-being.

In view of the identified risks, the To-Be scenario proposes a set of structured improvements. At the workstation level, the introduction of height-adjustable sinks would allow the work surface to be adapted to the worker's anthropometric characteristics, reducing trunk flexion and excessive elevation of the upper limbs. The use of anti-fatigue mats would help reduce lower limb fatigue associated with prolonged standing. Replacing the current water jet with a lighter, ergonomically designed model, combined with an articulated support arm to bear the weight of the jet, would significantly reduce physical effort.

The integration of smart technologies, such as automatic sensors to adjust water flow and collaborative robots for handling heavy utensils, would further contribute to reducing cognitive and physical workload. In addition, the implementation of scheduled micro-breaks—for example, 3 to 5 minutes every 30 minutes of activity—is recommended to reduce accumulated physical and mental fatigue. Partial task rotation with activities involving lower physical demands would allow variation in postural and muscular loads, while workload balancing during peak periods would reduce time pressure and individual overload.

These organizational and ergonomic measures contribute to reducing monotony and improving vitality and motivation, positively influencing well-being indicators assessed by the WHO-5 [26]. In terms of emotional and psychosocial well-being, strengthening operational autonomy, combined with improved physical working conditions and more balanced work organization, helps reduce the effort–reward imbalance, promoting greater job satisfaction and lower emotional strain.

In summary, the implementation of these improvements would allow the transformation of the “Dishwashing using a water jet” task from a physically demanding and repetitive process into a more balanced, human-centered system that reduces physical and psychosocial vulnerabilities and promotes a safer, more ergonomic, and emotionally sustainable work environment, in alignment with the principles of Industry 5.0.

4.4. TECHNICAL AND ECONOMIC JUSTIFICATION OF THE PROPOSED MEASURES

The analysis of the workstation “Dishwashing using a water jet” requires that the proposed measures be both technically sound and economically viable. Following the identification of the main physical, cognitive, and psychosocial risks, it became necessary to systematically justify the selection of each intervention, its expected impact on worker performance and well-being, and the way in which these measures contribute to a more efficient, safer workstation aligned with the principles of Industry 5.0.

The selection of measures was based on three essential criteria. The first was their direct impact on reducing the risks identified through the RULA, NIOSH, 5×5 Risk Matrix, NASA-TLX, SWAT, and psychosocial assessment tools. The second criterion concerned the cost–benefit relationship associated with the required investment. Finally, the compatibility of the solutions with a human-centered model—focused on enhancing human capabilities and promoting more sustainable work environments—was considered. Based on these criteria, interventions were selected that directly address the root causes of forced postures, unstable load handling, and

continuous cognitive demands, while simultaneously ensuring operational and organizational improvements.

From a technical perspective, replacing the current water jet with a lighter, ergonomically designed model, complemented by an articulated support arm, represents one of the most impactful interventions. This solution reduces static load on the upper limbs, the need for continuous gripping, and extreme joint ranges, contributing to lower RULA scores and reduced effort as identified by the NIOSH '91 Equation. Sustained reduction of these biomechanical demands is directly associated with a lower incidence of musculoskeletal disorders, reflected in decreased sick leave and reduced cumulative fatigue over time.

The implementation of height-adjustable sinks, as well as adjustable workbenches and anti-slip inclined modules, allows the workstation to be adapted to the worker's anthropometric characteristics, reducing trunk flexion and unsafe handling of wet dishes. In addition, the use of anti-fatigue mats contributes to reducing lower limb fatigue associated with prolonged standing. These measures mitigate mechanical risks identified by the 5×5 Risk Matrix and promote greater postural comfort, supporting sustained performance throughout the shift and reducing interruptions caused by physical discomfort.

At the cognitive level, the introduction of automatic dish-detection sensors and adaptive water-pressure control systems reduces the need for constant decision-making and continuous monitoring, directly impacting the reduction of mental workload as assessed by NASA-TLX and SWAT. Furthermore, the use of collaborative robots (cobots) to assist with the transport of heavy utensils significantly reduces physical effort and the risk of injuries associated with repetitive load handling. Stabilizing physical and cognitive demands contributes to lower psychological strain, a critical factor in reducing turnover in workstations characterized by repetitive and demanding tasks.

Additional measures, such as the use of high-grip gloves, anti-slip surfaces, and effective ventilation systems, enhance safety and thermal comfort, positively influencing emotional well-being indicators assessed by the WHO-5 and ERI instruments. A more stable and comfortable environment supports higher levels of motivation and job satisfaction—factors widely recognized as key determinants of worker retention and reduced absenteeism.

From an economic perspective, the proposed set of measures presents a favorable cost–benefit ratio. The most significant investments, such as the articulated arm, smart sensors, and cobots, correspond to structural improvements with measurable returns, reflected in reduced sick leave, lower turnover, and increased productivity resulting from a more stable work pace, fewer errors, and reduced rework. The phased implementation of solutions also allows costs to be distributed over time, beginning with low-investment, high-impact interventions such as layout reorganization, partial task rotation, and improvements to support surfaces.

In summary, the technical, economic, and organizational justification demonstrates that the proposed measures not only effectively reduce the identified risks but also generate sustainable gains in health, well-being, and performance. The evolution of the workstation toward a hybrid human–technology system embodies the principles of Industry 5.0, promoting a safer, more efficient, and more resilient work environment, with clear benefits for both the worker and the organization.

5. CONCLUSIONS

The article conducted a comprehensive assessment of the working conditions associated with jet dishwashing, considering physical, cognitive, and emotional risks simultaneously. The combined

use of assessment tools made it possible to accurately identify the factors that affect the worker's comfort, safety, and emotional balance.

The analysis revealed high levels of physical exertion, repetitive movements, monotony, time pressure and limited autonomy, aspects that contribute to greater wear and tear and potential impairment of performance. In view of these results, it became clear that there was a need to review the workplace and the methods used.

Based on Industry 5.0 principles, proposals have been outlined that include ergonomic improvements, task reorganisation, digital support, and the integration of smart technologies that facilitate work. These interventions seek to reduce physical and mental strain, improve workflow, and promote a more balanced and human-centred working environment.

In short, it reinforces the importance of an integrated approach to occupational health and safety, capable of preventing injuries, supporting emotional well-being and contributing to more efficient and sustainable operations.

ACKNOWLEDGEMENTS AND FUNDING

We would like to express our sincere gratitude to all those who contributed to the development and completion of this work.

First and foremost, we would like to thank our supervisors, Professors Marlene Brito and Maria Antónia Gonçalves, for their invaluable guidance, support, and encouragement throughout this research. Their expertise, insightful feedback, and dedication were essential in shaping the quality of this study.

We would also like to thank all colleagues and participants who generously provided their time, knowledge, and assistance during the data collection and analysis phases. Their cooperation made it possible for our team to carry out this work effectively.

Finally, we extend our heartfelt thanks to our families and friends for their constant encouragement and understanding during the preparation of this work.

This research would not have been possible without the support of all these individuals, to whom we are deeply grateful.

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Annex

Annex A – Integrated Risk Assessment – Physical Well-being

Table 5 - Risk assessment methods for each operation

Task	Operations	Risk Description	Risk	Ideal method
Wash the dishes with a jet	Carry the trays/pots	Damage to the spine, knees and ankles	Biomechanical	NIOSH'91 Equation
		Falling wet and slippery loads	Mechanical	5×5 Matrix
	Put the dishes in the kitchen	Spinal damage	Biomechanical	REBA
	Use the jet to remove dirt	Burns	Physical	5×5 Matrix
		Damage to the wrists and forearms	Biomechanical	RULA

Table 6 - Grip Multipliers

Grip quality	Grip multipliers	
	V < 75 cm	V ≥ 75 cm
Good	1.00	1.00
Acceptable	0.95	1.00
Poor	0.90	0.90

Table 7 - Grip Quality

Grip Quality	Conditions
Good	W ≤ 40 cm, H ≤ 30 cm and good grips or cut-outs Grip length ≥ 11.5 cm and 2 < Ø < 4 cm Easy to handle due to the presence of points that are easy to grip Grip surface allowing good grip with the hand
Acceptable	Object with structural rigidity and W ≤ 40 cm, H ≤ 30 cm and poor grips or cut-outs, or W ≤ 40 cm, H ≤ 30 cm and angle of fingers to palm ≤ 90°
Poor	W > 40 cm or H > 30 cm or difficulty in picking up or unstable centre of gravity (liquids, granular materials, etc.) or asymmetrical centre of gravity

Table 8 - Frequency Multiplier

Frequency (beats per minute) (1)	Duration of period with lifting tasks, T					
	T ≤ 1 h		1 < T ≤ 2 h		2 < T ≤ 8 h	
	V < 75	V ≥ 75	V < 75	V ≥ 75	V < 75	V ≥ 75
0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.70	0.70	0.42	0.42	0.22	0.22
8	0.60	0.60	0.35	0.35	0.18	0.18
9	0.52	0.52	0.30	0.30	0.00	0.15
10	0.45	0.45	0.26	0.26	0.00	0.13
11	0.41	0.41	0.00	0.23	0.00	0.00
12	0.37	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00
(1) For frequencies lower than 1 in every 5 minutes, consider F = 0.2						

Table 9 - 5×5 Matrix

			Severity				
			1	2	3	4	5
			Insignificant	Slight	Moderate	Severe	Catastrophic
Frequency	1	Very unlikely	1	2	3	4	5
	2	Unlikely	2	4	6	8	10
	3	Possible	3	6	9	12	15
	4	Likely	4	8	12	16	20
	5	Very likely	5	10	15	20	25

Annex B – Identification of Opportunities and Construction of the To-Be Scenario (Industry 5.0)

Table 10 - As-Is vs. To-Be Comparison

Risk	Method	As-Is	To-Be	Health and wellbeing benefits
Physical wellbeing				
Biomechanical	NIOSH'91 Equation	RWL = 3.28 kg; high frequency (Frequency Multiplier = 0.42); effort close to/above recommended	Increased RWL (↓ frequency / ↓ effective weight); effort within recommended limits	↓ lumbar risk; ↓ physical exertion; ↓ likelihood of chronic pain
Mechanical and Physical	5×5 Matrix	Falling wet and slippery loads = 8 = moderate Burns = 12 = high	Falling wet and slippery loads = 4 = low Burns = 6 = moderate	↓ probability of accidents; ↓ severity of consequences; ↑ operational safety
Biomechanical	REBA	11 Very high risk	4-5 Moderate to low risk	↓ strain on the spine and shoulders; ↑ postural comfort; ↓ discomfort throughout the shift
Biomechanical	RULA	7	3-4	↓ risk of musculoskeletal injuries in the upper limbs; ↓ muscle fatigue; ↓ likelihood of chronic pain
Cognitive wellbeing				
High mental load	NASA-TLX	High overall mental load, with emphasis on physical demands, effort and frustration	Moderate mental load	↓ cognitive overload; ↓ mental fatigue; ↑ sustained performance
Stress associated with time and effort	SWAT	High time demands and continuous physical effort	Moderate time commitment and effort	↓ operational stress; ↑ perceived control of the task
Cognitive complexity of the task	GOMS	Sequence of repetitive actions requiring continuous attention and constant micro decisions	More stable and predictable sequence	↓ need for constant decisions; ↑ secure automation
Operational human error	SHERPA	Moderate probability of errors due to fatigue, distraction or time pressure	Reduced probability of error	↓ human error; ↑ task safety and reliability
Emotional and psychosocial wellbeing				
Occupational stress	HSE Standards	High demands, frequent time pressure and little control over the pace	Moderate requirements and greater predictability	↓ occupational stress; ↑ emotional balance

Risk	Method	<i>As-Is</i>	<i>To-Be</i>	Health and wellbeing benefits
Repetitiveness and emotional exhaustion	COPSOQ	High repetitiveness, monotony and abrupt changes in pace	More stable rhythm and less monotony	↓ emotional exhaustion; ↑ job satisfaction
Low operational autonomy	JCQ	Reduced autonomy and limited control over task organisation	Greater margin for decision-making in execution	↓ psychological stress; ↑ sense of control
Effort–reward imbalance	ERI	High physical and emotional effort with limited recognition	A more balanced relationship between effort and recognition	↓ frustration; ↑ motivation and engagement
Emotional fatigue and reduced overall wellbeing	WHO-5	Low levels of energy, vitality and wellbeing throughout the shift	Moderate to high levels of wellbeing	↑ vitality; ↓ emotional fatigue

Annex C – Cook Assessment Questionnaire

Questionário de Avaliação das Cozinheiras

1. Localidade:
Vila Nova de Gaia
2. Idade: 51 anos 3. Peso: 59 Kg 4. Altura: 1,63 cm
3. Género:
☒ Feminino
☐ Masculino
4. Qual é o seu nível de escolaridade?
☐ Não sabe ler nem escrever
☐ Sabe ler e escrever
☐ 4.º ano
☐ 6.º ano
☐ 9.º ano
☒ 12.º ano
☐ Bacharelato/Licenciatura
☐ Outra: _____
5. É fumadora?
☒ Sim
☐ Não
6. Tem algum problema de saúde?
☐ Sim
☒ Não
Se sim, qual?
☐ Músculo-esquelético
☐ Respiratório
☐ Dermatológico
☐ Cardiovascular
☐ Psíquico
☐ Neurológico
☐ Neoplásico
☐ Outro: _____
7. Trabalha na cozinha há quantos anos? 20
8. Que tipo de cozinha?
☐ Restaurante

Figure 7 - Cook Assessment Questionnaire – Page 01

- ☒ Cantina escolar
☒ Unidade hospitalar
☐ Padaria/pastelaria
☐ Hotel
☐ Catering
☐ Outra: _____
9. Em média, quanto tempo trabalha por dia?
Horas/dia: 10 Dias/semana: _____
10. O seu turno é normalmente:
☒ Manhã
☐ Tarde
☐ Noite
11. Como organiza o seu trabalho?
☐ Executo a mesma tarefa durante várias horas
☒ Alterno entre tarefas ao longo do dia
☐ Interrompo quando estou cansada
☐ Outras: _____
12. Faz pausas durante o trabalho?
☒ Sim
☐ Não
13. Sente dores durante o trabalho na cozinha?
☐ Sim
☒ Não
Se sim, onde (assinalar todas as queixas):
☐ Cervical
☐ Ombros
☐ Cotovelos
☐ Punhos/mãos
☐ Dorsal
☐ Lombar
☐ Ancas
☐ Joelhos
☐ Tornozelos/pé
15. Como realiza o corte de alimentos?
☒ Com faca, repetindo o movimento várias vezes
com faca

Figure 8 - Cook Assessment Questionnaire – Page 02

- ☐ Com faca pesada que exige força
- ☒ Em bancada baixa (preciso inclinar o tronco)
- ☐ Em bancada alta (elevo demasiado os ombros)
- ☐ Com robot de cozinha
- ☐ Outra: _____
16. Quando está a levantar panelas, tabuleiros ou tachos quentes, o que faz?
- ☒ Levanto sozinho(a)
- ☒ Peço ajuda
- ☐ Inclino o tronco para a frente
- ☐ Dobro os joelhos
- ☒ Utilizo luvas térmicas adequadas
- ☐ Outra: _____
17. Para mexer panelas grandes ou caldeirões:
- ☐ Uso força dos braços
- ☐ Rodo o tronco repetidamente
- ☐ Aproximo-me muito da fonte de calor
- ☐ Uso utensílios longos/adequados
- ☐ Outra: _____
18. Para transportar cargas na cozinha:
- ☐ Transporte manualmente
- ☐ Transporte tabuleiros ao ombro
- ☒ Empurro carrinhos
- ☐ Transporte caixas pesadas
- ☐ Não transporto cargas
- ☐ Outra: _____
19. Para alcançar ingredientes/equipamentos:
- ☐ Estico os braços acima da cabeça
- ☐ Uso banco/escadote
- ☒ Peço ajuda
- ☐ Não faço esta tarefa
20. Trabalha exposta a:
- Calor excessivo ☐ Sim ☒ Não
- Vapor ☒ Sim ☐ Não
- Ruído (exaustores/máquinas) ☒ Sim ☐ Não

Figure 9 - Cook Assessment Questionnaire – Page 03

Produtos químicos de limpeza ☒ Sim ☐ Não
Fumos de fritos ☐ Sim ☒ Não

21. Que postura usa mais frequentemente?

☐ Tronco inclinado para a frente
☐ Tronco torcido (rotação)
☐ Braços elevados ao nível dos ombros
☐ Permanência prolongada de pé
☒ Caminhar longas distâncias na cozinha
☐ Outra: _____

22. Em que medida está satisfeita com o trabalho na cozinha?

1 Muito Insatisfeita
2 Insatisfeita
3 Pouco Satisfeita
4 Satisfeita
☒ 5 Muito Satisfeita
6 Sem opinião

23. Posturas de Trabalho

Assinale as posturas que adota frequentemente:

☐ Trabalhar com o tronco inclinado para a frente
☒ Torcer o tronco repetidamente (rotação para fogão, bancada, prateleiras)
☐ Braços elevados acima do nível dos ombros
☒ Permanecer longos períodos de pé
☒ Agachar para alcançar prateleiras baixas
☐ Esticar-se para prateleiras altas
☐ Outra: _____

24. Movimentos Repetitivos

☐ Cortar, picar ou preparar alimentos manualmente
☐ Mexer panelas, tachos ou recipientes de grande volume
☐ Bater massas, temperos ou misturas manualmente
☒ Lavar grandes quantidades de louça ou utensílios
☐ Abrir e fechar portas de armários/frigoríficos continuamente
☐ Embalar ou porcionar refeições
☐ Passar pratos entre bancadas ou zonas de serviço
☐ Outro movimento repetitivo: _____

Figure 10 - Cook Assessment Questionnaire – Page 04

25. Levantamento e Transporte de Cargas:
- Panelas ou tachos pesados (com alimentos ou água)**
☒ Nunca ☐ Raramente ☐ Às vezes ☐ Frequentemente ☐ Sempre
- Tabuleiros grandes ou cheios (ex.: assadeiras, tabuleiros de forno)**
☐ Nunca ☐ Raramente ☒ Às vezes ☐ Frequentemente ☐ Sempre
- Caixas de alimentos, sacos de ingredientes ou garrações**
☐ Nunca ☐ Raramente ☐ Às vezes ☒ Frequentemente ☐ Sempre
26. Condições Ambientais do Posto de Trabalho
- Calor e Temperatura**
 Calor intenso devido a fogões, fritadeiras ou fornos?
☒ Sim ☐ Não
- Humidade e Vapor**
 Exposição constante a vapor e humidade elevada?
☒ Sim ☐ Não
- Ruído**
 Níveis elevados de ruído (exaustores, máquinas industriais, louça)?
☒ Sim ☐ Não
- Produtos Químicos**
 Contacto direto ou indireto com produtos de limpeza ou desinfeção?
☒ Sim ☐ Não
- Condições de Piso**
 Pisos escorregadios, húmidos ou irregulares?
☒ Sim ☐ Não
- Ventilação**
 Considera a ventilação adequada durante o seu turno?
☐ Sim ☒ Não
27. Organização e Ritmo de Trabalho:
- ☒ Trabalho frequentemente acelerado devido ao horário de refeições
☐ Pausas insuficientes ou irregulares
☒ Multitarefa constante (cozinhar, lavar, servir, preparar)
☒ Mudanças frequentes entre tarefas pesadas e tarefas precisas
☐ Outra situação relevante: _____
28. Equipamentos e Ferramentas:
- Altura adequada das bancadas de trabalho**
☐ Sim ☒ Não ☐ Parcialmente
- Facas e utensílios em boas condições ergonómicas**
☒ Sim ☐ Não
- Acesso fácil a utensílios e ingredientes (não obriga a esticar/torcer)**

Figure 11 - Cook Assessment Questionnaire – Page 05

☒ Sim ☐ Não

Uso de tapetes anti-fadiga

☒ Sim ☐ Não

Figure 12 - Cook Assessment Questionnaire – Page 06

Annex D – Comparison of Results with Similar Studies

Table 11 - Comparison of Results with Similar Studies

Aspect	Chim (2006)	Present study
Type of analysis	Global ergonomic analysis	Integrated workstation assessment
Physical effort assessment	Borg RPE Scale	RULA, REBA, NIOSH'91 Equation
Physical/mechanical risk assessment	Qualitative assessment	5×5 Matrix
Improvement proposal	Generic ergonomic redesign	Ergonomic, organizational and technological measures