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BLOOD PRESSURE PROFILE AND SHIFT WORK IN FIREFIGHTERS

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Abstract

Background: Hypertension is a global concern, as it is one of the main cardiovascular risk factors. There are many factors that can contribute to high blood pressure, and shift work may be one of them. Firefighters are exposed to shift schedules, this being only one of the multiple other occupational stressors, therefore increasing cardiovascular risk. **Objectives:** To evaluate the blood pressure profile of firefighters, assess the influence of shift work, and determine the prevalence of hypertension. **Methodology:** A cross-sectional study was conducted in 41 firefighters, mean age 45.61 (± 7.98) years using an Ambulatory Blood Pressure Monitoring (ABPM). **Results:** We found 18 individuals with hypertension, of whom 6 were previously diagnosed. A positive correlation was found between the measurements before and after the shift and the mean daytime arterial pressure. Additionally, a statistically significant association was found between the circadian blood pressure variation and hypertension. **Conclusions:** Shift work has an influence on the blood pressure profile of these individuals, demonstrated not only from the correlation of measurements before and after the shift, but also due to the altered circadian blood pressure variation. These findings highlight the need for cardiovascular surveillance and preventive strategies in this occupational group.

Keywords: Ambulatory Blood Pressure Monitoring, Firefighters, Occupational Health, Shift Work, Circadian Variation of Blood Pressure.

1. Introduction

Blood pressure is a major public health concern, representing one of the leading risk factors for cardiovascular morbidity and mortality worldwide (Oliveros *et al*., 2020). According to the Portuguese National Health System, 42.6% of the Portuguese adult population is hypertensive, and of the hypertensive patients, less than half are medicated, and only 11.2% are controlled (SNS 24, n.d.).

Hypertension affects the body in general, however, it is the organs such as the heart, brain, kidneys, eyes and blood vessels that are most affected. This results in hypertension-mediated organ damage (HMOD), leading to structural and functional changes, associated with the onset of cerebrovascular diseases (stroke and cognitive decline), kidney diseases (acute or chronic) and heart diseases (heart failure, atrial fibrillation, valvular diseases and coronary artery disease) (McEvoy *et al*., 2024).

The main factors that can lead to increased blood pressure are stress, excess weight, excessive intake of salt, sugar or alcohol, smoking and other factors (Carretero & Oparil, 2000; Rossi *et al*., 2020). However, there are other less studied causes that can lead to increases in blood pressure. Shift work, although it has not yet been proven and is still under active investigation, has been suggested as one potential factor. Night shifts have been linked to atherosclerosis, diabetes, metabolic syndrome and some sleep disorders. Furthermore, shift workers present changes in the circadian variation of blood pressure, which will be discussed later (Cunha *et al*., 2023).

Many professions involve shift work, including firefighting. It is a high demand profession, characterized by constant alertness, high stress, smoke exposure (polycyclic aromatic hydrocarbons [PAHs] and volatile organic compounds [VOCs]), heavy personal protective equipment (PPE), intense physical exertion, high temperatures, dehydration, as well as the individual cardiovascular risk factors. This profession is essential to our society, highlighting the importance of higher vigilance and control (Sjöström *et al*., 2019; RPSO, 2021).

The rate of cardiovascular disease is high in this profession, with 50% of in-service deaths being caused by sudden cardiac events, making it higher than the general population (Cunha *et al*., 2023). About 80% of these fatalities are caused by coronary heart disease and cardiac structural enlargement such as cardiomegaly or ventricular hypertrophy. Some of which are caused by remodelling effects, often justified by high blood pressures (Choi *et al*., 2016).

Thus, this study aims to evaluate a firefighter population to assess the influence of shift work and occupational demands on their blood pressure profile, using Ambulatory Blood Pressure Monitoring (ABPM), and to analyse their associated cardiovascular risk.

2. Materials and Methods

2.1 Study Design

This study is a cross-sectional observational study, achieved with the voluntary participation of 41 firefighters, who underwent an ABPM. This test was conducted after the day shift until the beginning of the night shift the following day. The placement and explanations about the ABPM, and the completion of a questionnaire were conducted at the facilities of the Fire Brigade Company.

2.2 Study Population

The population of this study were Firefighters from a Fire Brigade Company.

The inclusion criteria were adults aged over 18, firefighters belonging to the Fire Brigade Company and of both genders. Consequently, the exclusion criteria were minors, firefighters who did not belong to this company and individuals who had been diagnosed with any previous heart disease, excluding arterial hypertension.

In order to ensure that this research preserves human rights, all the firefighters who took part in this study did so of their own free will, and all signed an informed consent form after being explained about the study's objectives and how it would be carried out. Each individual was given a participant number in order to guarantee their anonymity as well as the data obtained.

2.3 Procedure

The ABPM was performed between two shifts, starting after the end of the day shift (9 pm). Participants then went home, and the exam ended before the start of the following night shift (9 pm). Thus, ABPM was conducted outside working hours, as performing it during duty was considered unsafe and could compromise both performance and quality of the exam, representing a limitation of this study.

Primarily, participants received an explanation of the study's objectives, methodology, and data collection procedures. They then read and signed the informed consent form and completed a short questionnaire collecting data on age, sex, weight, height, years of service, number of monthly shifts, smoking status, diet type, physical activity, and history of hypertension or other cardiovascular diseases.

Next, a Riva-Rocci cuff, selected according to arm circumference, was placed on the participant's arm, and the device was secured around the waist in a protective pouch.

Participants were then instructed on device operation and necessary precautions. The ABPM was programmed to measure every 20 minutes during the day (08:00–21:00) and every 30 minutes during the night (21:00–08:00). It was explained that when the device beeped, a measurement was about to begin, and they should keep their arm relaxed along the body or resting on a stable surface until a second beep indicated completion, after which they could resume their activities.

Before leaving, an initial manual blood pressure measurement was taken to initiate the program and served as the office measurement.

The following day, prior to returning to work, the device was removed, and the data were downloaded into the software. To complete the dataset, participants were also asked to report their bedtime and wake-up time.

2.4 Classification and Collection of Ambulatory Blood Pressure Measurement

In this study, ABPM data was obtained from 41 Firefighters. After the end of the study, each individual's data was downloaded to the Mobil-O-Graph software, model NBP-24 NG.

This test provided the following data: 24-hour, daytime and nighttime mean values for Systolic; Diastolic and Mean Blood Pressure; Heart Rate and Pulse Pressure, as well as Circadian Variation in Blood Pressure and the Standard Deviation of Systolic Blood Pressure, Diastolic Blood Pressure and Heart Rate.

In order to classify the individual's blood pressure profile, as well as the classification of circadian variation of blood pressure, we followed the guidelines taken from the European Society of Cardiology (ESC).

It was defined as hypertension when daytime systolic blood pressure ≥ 135 mmHg and/or diastolic blood pressure ≥ 85 mmHg, nighttime systolic blood pressure ≥ 120 mmHg and diastolic blood pressure ≥ 70 mmHg, 24-hour mean systolic blood pressure ≥ 130 mmHg and diastolic blood pressure ≥ 80 mmHg (McEvoy *et al*., 2024).

For the classification of office blood pressure, we used the following classification. Excellent when systolic pressure was <120 mmHg and diastolic pressure <80 mmHg, normal when systolic pressure ranged between 120–129 mmHg and/or diastolic pressure between 80–84 mmHg, high normal when systolic pressure ranged between 130–139 mmHg and/or diastolic pressure between 85–89 mmHg; hypertension type 1 when systolic pressure ranged between 140–159 mmHg and/or diastolic pressure between 90–99 mmHg, hypertension type 2 when systolic pressure ranged between 160–179 mmHg and/or diastolic pressure between 100–109 mmHg and hypertension type 3 when systolic pressure was ≥180 mmHg and/or diastolic pressure ≥110 mmHg (McEvoy *et al*., 2024).

In order to clarify the blood pressure classification, we also analysed the blood pressure load and the results of individual measurement. Individuals whose 24 hour mean blood pressure load

exceeded 50% were considered for hypertension and were evaluated in conjunction to other factors. The blood pressure load is the percentage of measurements above the normal range (Eyal and Ben-Dov, 2023).
Regarding the circadian variation of blood pressure, we used the following classification, extreme dipper (>20%), normal dipper (10–20%), non-dipper (0–10%), and reverse dipper (<0%), based on the percentage of nighttime blood pressure reduction relative to daytime values (McEvoy *et al*., 2024). The night period was studied individually.
It is also important to mention that the hypertensive patients previously diagnosed and medicated were classified as hypertensive for this study.

2.5 Statistical Analysis

The data obtained in the survey, as well as the ABPM results, were registered in Excel 2025 (Microsoft Excel, version 16.94) and then imported into IBM SPSS Statistics version 29 for statistical analysis.
SPSS tools were used to describe quantitative variables, analysed based on mean, standard deviation, minimum and maximum, and qualitative variables, analysed through frequency and percentages. We also performed a description by groups of hypertensive and normotensive of the variables described.
To compare the variable, “ABPM diagnosis”, with two groups, hypertensive and normotensive, the U Mann-Whitney test and Exact Fisher's test were used for the quantitative and qualitative variables respectively, assessing the probability value, p, in both cases. A statistically significant relationship was considered when $p<0.05$. The Wilcoxon’s non-parametric test of two paired variables was used to evaluate the paired comparison between two quantitative variables. The probability value was assessed using the same rule as described above.

3. Results

3.1 Main results

This study assessed 41 Firefighters, 40 male and 1 female.
For the sociodemographic characterization of this sample, which data was collected using the questionnaire, we have a sample with age of 45,61 ± 7,98, being the oldest of 58 years old and the youngest 24 years old, weight of 78,13 ± 7,21, height 1,73 ± 0,05, BMI 26,07 ± 2,23, years of service, 23,34 ± 8,52 and number of shifts per month 14,98 ± 1,26.
There were 40 male participants and 1 female, 29 were nonsmokers (70,7%), 7 smokers (17,7%) and 5 ex-smokers (12,2%), 36 had a balanced diet, 2 with high salt consumption and 5 with high sugar consumption. Of the participants, 11 did little daily activity, 28 a normal quantity and 2 high quantities. As for the shift prior to the ABPM, 9 had a calm shift (22,0%), 29 moderate (70,7%) and 3 intense shift (7,3%)
In order to analyse each individual's blood pressure profile, in addition to the values obtained by ABPM, an office blood pressure was assessed. For this, it was considered the first measurement, which was taken manually when the device was installed, to start the program.
The mean office systolic blood pressure was 133.24 ± 13.58 mmHg, with values ranging from 109 to 175 mmHg, while the mean diastolic blood pressure was 90.39 ± 7.97 mmHg, ranging from 67 to 108 mmHg.
Based on office blood pressure classification, 7.3% of participants had excellent values, 9.8% normal, 22.0% normal-high, 51.2% hypertension type 1, and 9.8% hypertension type 2. Overall, 61.0% of the sample was classified as hypertensive, 25 of the participants.

Next, we look at the ABPM and the results obtained from it.
Mean daytime, nighttime, and 24-hour systolic blood pressure values were 124.24 ± 11.38 mmHg, 110.24 ± 9.07 mmHg, and 120.22 ± 10.63 mmHg, respectively, while corresponding diastolic values were 81.90 ± 8.07 mmHg, 68.68 ± 7.05 mmHg, and 78.05 ± 7.58 mmHg.
Mean daytime, nighttime, and 24-hour MAP values were 101.44 ± 8.98 mmHg, 87.66 ± 7.15 mmHg, and 99.61 ± 17.56 mmHg, respectively. Mean heart rate was higher during daytime, 66.80 ± 9.51 bpm, than nighttime, 55.37 ± 7.16 bpm, with a 24-hour mean of 63.17 ± 7.99 bpm. Mean pulse pressure was 42.20 ± 7.30 mmHg, and average nocturnal systolic and diastolic dipping were 11.09 ± 4.51% and 15.93 ± 6.03%, respectively. Blood pressure variability, expressed as standard deviation, was 12.08 ± 2.94 mmHg for systolic pressure and 9.64 ± 2.46 mmHg for diastolic pressure, while heart rate variability showed a standard deviation of 9.38 ± 3.26 bpm.
As for the general results of the ABPM, based on the values obtained during the test and according to ABPM classification, hypertension was detected in 43.9% (n=18) of the sample, whereas 56.1% (n = 23) were normotensive.

3.2 Blood Pressure Profile and the Shift

The ABPM was performed between shifts to observe fluctuations in various phases, immediately after the shift, the relaxation caused by rest, the night period; the day off and the moments just before the start of the next shift. In order to analyse whether there really is a difference between the moments after, before and outside the shift, the first 2 measurements post and pre-shift were analysed, producing the following results.
After the shift, mean systolic blood pressure was 131.84 ± 13.77 mmHg, with values between 108.5 and 175.0 mmHg. Mean diastolic blood pressure also was 88.27 ± 8.24 mmHg, ranging from 71.0 to 106.5 mmHg.
Before the shift, the mean systolic blood pressure was 126.67 ± 12.79 mmHg, with values ranging from 93.0 to 157.0 mmHg, while the mean diastolic blood pressure was 83.71 ± 8.87 mmHg, ranging from 63.5 to 104.5 mmHg.
To try to analyse this difference numerically, its divergence was analysed. This difference was made individually for each participant, rather than between total averages, to obtain a more reliable result of each individual's fluctuations.
Before the shift, the mean difference observed between the first and last measurements for systolic blood pressure were of 2.43 ± 9.11 mmHg and diastolic blood pressure of 1.81 ± 6.25 mmHg. After the shift, these differences were higher, 7.60 ± 8.52 mmHg and 6.37 ± 6.52 mmHg, respectively.
In order to observe these fluctuations visually, the following figure shows the hourly averages for all the subjects, for systolic and diastolic blood pressure and heart rate.

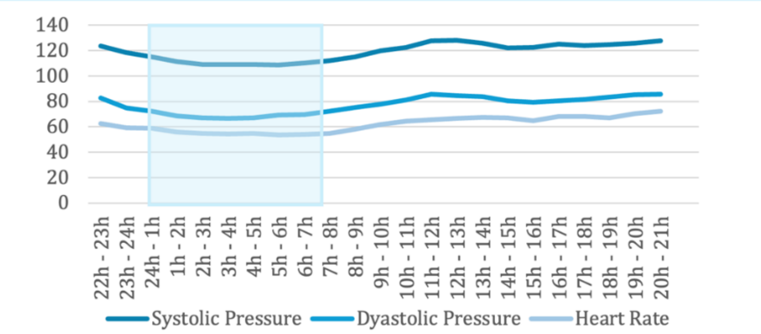

Figure 1 - Hour deviation of Blood Pressure, Systolic and Diastolic and Heart Rate obtained by the ABPM

We were able to observe a decrease from the beginning of the ABPM, and end of the day shift, until the average bedtime of the participants (23h40). After 23h40 we observe a drop in blood pressure, which corresponds to the night drop. After awakening, which the average of the participants is at 7h34, we observe an increase, and between 12h00 and 19h00 we observe a plateau. Starting at 19h00 there is an increase, until the end of the test, and beginning of the night shift.

3.3 Statistical Results of ABPM and Blood Pressure profile

In order to carry out a correlational analysis of ABPM results between individuals with or without hypertension and the different variables analysed, some statistical tests were carried out. The U Mann-Whitney test for 2 independent variables was used for all quantitative variables. Fisher's exact qui-square test was used for the qualitative variables.

Table 2 and 3 show the probability value for the hypertensive and normotensive groups, classified by ABPM results and the different quantitative variables obtained in the test and table 4 and 5 for the qualitative variables. The signalised p values are the ones with statistical significance.

***Table 1**: Correlational analysis of the quantitative variables obtained by ABPM between the hypertensive and normotensive groups*

Quantitative variables	**Mean daytime Systolic Pressure**	**Mean night Systolic Pressure**	**24-hour mean Systolic Pressure**	**Mean daytime Diastolic Pressure**	**Mean night Diastolic Pressure**
	< .001	0.006	< .001	< .001	< .001
	24-hour mean Diastolic Pressure	Office Systolic Pressure	Office Diastolic Pressure	Mean daytime MAP	Mean night MAP
	< .001	0.350	< .001	< .001	< .001
	24-hour mean MAP	Mean daytime HR	Mean night HR	24-hour mean HR	24-hour mean Pulse Pressure
	< .001	0.875	0.453	0.802	0.571
	Dipper Systolic Pressure percentage	Dipper Diastolic Pressure percentage	Systolic Pressure standard deviation	Diastolic Pressure standard deviation	HR standard deviation
	0.002	0.431	0.001	0.007	0.478

***Table 2:** Correlational analysis of the quantitative variables obtained in the questionnaire between the hypertensive and normotensive groups*

Quantitative variables	**Age**	**Wright**	**Height**	**BMI**	**Years of service**	**Average number of shifts per month**
	0.151	0.158	0.199	0.008	0.321	0.228

Table 3: *Correlational analysis of the qualitative variables obtained in the questionnaire between the Hypertensive and Normotensive groups*

Qualitative variables	**Sex**	**Smoking status**	**Nutrition**	**Hight salt consumption**	**High sugar consumption**
	0.439	1.000	0.150	0.187	0.638
	Daily physical activity	Effort during shift	Cardiovascular disease	Cholesterol	BMI classes
	0.033	1.000	0.004	0.724	0.019

Table 4: *Correlational analysis of the qualitative variables obtained in ABPM between the hypertensive and normotensive groups*

Qualitative variables	Systolic Circadian Variation	Diastolic Circadian Variation	Pulse Pressure classes
	0.006	0.320	0.187

To analyse whether there is an influence of the shift on the blood pressure profile of the firefighters, comparisons between pre and post-shift blood pressure values were performed using the Wilcoxon. To do this, some statistic tests were carried out. The first 2 measurements after and before the shift were analysed, and the mean daytime systolic and diastolic blood pressures were averaged separately. This resulted in 4 different variables, mean daytime systolic blood pressure after and before the shift and mean daytime diastolic blood pressure after and before the shift. The non-parametric Wilcoxon two-sample paired test was used. If $p<0.05$ there was a statistically significant difference, the results were the following.

Mean daytime systolic and diastolic blood pressure values were significantly correlated with post-shift measurements (both $p < 0.001$). No significant correlation was observed for systolic blood pressure before the shift ($p = 0.085$), whereas diastolic blood pressure showed a weaker but significant correlation ($p = 0.044$).

4. Discussion

The profession of firefighter is a highly demanding occupation, as they are constantly exposed to adverse conditions that imply high levels of physical effort, thereby increasing the cardiovascular risk (Ras *et al*., 2022). In our study, 43.9% of the participants were hypertensive, highlighting the need for closer monitoring, since this is one of the main cardiovascular diseases. The Portuguese Journal of Occupational Health (RPSO) states that the high incidence of hypertension and/or atherosclerosis in firefighters can be explained by the inhalation of particles resulting from fires that lead to increased arterial stiffness (RPSO, 2021).

The cardiovascular risk of these individuals increases when risk factors, such as obesity, hypertension, diabetes, dyslipidaemia, smoking, physical inactivity are associated with other factors that accompany the profession, such as thermal discomfort, chronodisruption, biological agents, respiratory, cardiac and oncological risks, among others. This combination raises the incidence of occupational diseases and associated mortality, which is higher than in the general population (Choi *et al*., 2016).

The circadian variation of blood pressure is a subject that has been a major focus in this study, as there is a relationship between blood pressure variation, shift work and hypertension, particularly among male and rotating shift workers (Costello & Gumz, 2021; White, 2000). Shift work causes chronodisruption, altering the pattern of biological clocks and consequently altering the normal progression of blood pressure. In these cases, there is reduction in nocturnal blood pressure dipping, and, in the long term, can induce hypertension (Cunha *et al*., 2023).

The reduction of nocturnal blood pressure descent, also known as the non-Dipper pattern, is an important indicator for estimating an individual's cardiovascular risk. This pattern has significant clinical relevance, as it is directly associated with hypertension-mediated organ damage, an increased risk of future cardiovascular events, renal dysfunction and disorders of the sympathetic nervous system (Birkenhäger & Van Den Meiracker, 2007; Costello & Gumz, 2021).

In our study, 48.8% of the participants had a weak nocturnal drop in blood pressure. Of the remainder, 48.8% had a normal circadian variation in blood pressure, and 1 individual was an extreme Dipper, indicating a high prevalence of circadian alterations. Statistical analysis revelled a significant relationship between the systolic circadian variation and hypertension, and that there may be a potential causal relationship between these two variables. (Birkenhäger & Van Den Meiracker, 2007; Cunha *et al*., 2023).

Diastolic-predominant hypertension is present in this population, as 8 of the 18 hypertensive patients have this pattern. Isolated diastolic hypertension is associated with higher cardiovascular risk, increasing therefore the mortality from cardiovascular disease and coronary heart disease (Yano *et al*., 2022; Agarwal *et al*., 2024; Huang *et al*., 2022).

Shift work was approached indirectly, as the ABPM test could not be carried out during a shift due to the implications and limitations it would have for the firefighter, as mentioned before. However, significant correlations were found between post-shift and daytime blood pressure, as well as between daytime and pre-shift diastolic pressure. Blood pressure was significantly higher in the first hour after and before shifts, likely due to physical exertion during duty and anticipatory stress before starting work.

Although we were unable to assess blood pressure profiles during duty shifts, previous studies confirm how emergency alarms trigger sympathetic activation, increasing heart rate and blood pressure, which could contribute to the on-duty cardiac deaths (Feairheller *et al*., 2023). Rynne *et al*. (2023) showed that there was an 11% increase in systolic pressure and a 10.5% increase in diastolic pressure. Similarly, Feairheller *et al*. (2023) reported a 13.5% increase in systolic pressure and 8.8% in diastolic blood pressure.

These findings suggest that this population is more vulnerable, as sudden rises in blood pressure have consequences at various levels, particularly at the cardiovascular level, which may explain the high percentage of on-duty deaths. To further highlight this problem, the increase in pressure is greater in hypertensive firefighters, amplifying the cardiovascular risks (Feairheller *et al*., 2023).

Regarding Mean Arterial Pressure (MAP), higher values have been associated with increased long-term risk of cardiovascular events (DeMers & Wachs, 2023). In our study, daytime, nighttime, and 24-hour average MAP values demonstrated significant associations with hypertension diagnosis (Melgarejo *et al*., 2020).

Although pulse pressure is an important marker of cardiovascular risk, in this study, only two individuals presented elevated pulse pressure. Statistical analysis did not reveal a significant association between these values and the diagnosis of hypertension (Homan *et al*., 2023).

5. Study Limitations

A main limitation of this study was the use of ABPM during work shifts, which could affect job performance and measurement validity due to continuous movement. Therefore, ABPM was conducted between shifts to minimise interference, which may have influenced correlations with shift-related variables.

6. Conclusions

We conclude that the profession of firefighting is associated with significant alterations in blood pressure profiles, in addition to daily occupational exposures that increase cardiovascular risk (Cunha *et al*., 2023; Rossi *et al*., 2020). The main findings supporting the link between shift work and blood pressure changes were the altered circadian variation and the significant differences between pre- and post-shift measurements and the remaining daytime values.

Overall, this population experiences considerable cardiovascular burden, due to the conditions and implications of this profession. For these very reasons, these professionals should have more regular health checks in order to avoid the onset of cardiovascular pathologies and prevent them from decline in health, and consequentially on-duty deaths, strongly associated with elevated cardiovascular risk and hypertension (Cunha *et al*., 2023).

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