Influence of permanent night work on the circadian rhythm of blood pressure

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Abstract. Night workers exercise their labours activities and rest in contrary schedules to the chronobiological standards. This inversion leads the body to several adaptations, including changes in the circadian rhythm of blood pressure (BP). Objectives: To evaluate the BP in individuals who perform work at night, in order to objectively detail the BP circadian rhythm adaptations infixed night workers. Methods: A cross-sectional study enrolling 23 fixed night workers, both genders, was performed, with 24h BP measured with ambulatory blood pressure monitoring (ABPM) during a normal working day. Risk factors, anthropometric and lifestyle information were collected using a standard questionnaire. Results: Ambulatory BP demonstrated a pattern of adaptation to the sleep/activity cycle in all participants. BP dropped during the sleeping period (mean drop: -11.35±6.85) and was higher during the awakening period, reaching the highest results and greater BP variability during the working period. The chronobiological adaptation of the 24h BP was not dependent on sociodemographic or clinical characteristics. In addition, age, male gender, obesity, and those working less time were associated with higher BP mean values. Conclusions: The circadian rhythm of BP follows the working circadian profile of the individual.

Keywords: Permanent night work; Arterial pressure; Circadian Rhythm

1 Introduction

1.1 Night work and health impacts

The night work regime has been linked to a greater predisposition to organic imbalance and disturbances, from which health hazards are more prevailing and projected over the different dimensions of health, including physical wellbeing as well as mental, emotional and social stability[1]. Following a working schedule unmatched with the chronobiological standard, implies sleeping cycles adjusted for periods of biological arousal (daytime), and conversely, activity during periods when [illegible] lower [illegible] vioral adjustments must be followed by changes in the circadian rhythms of various physiological variables[2,3], which in turn have been associated with sleep disturbances, gastrointestinal problems, depressive and/or anxious symptoms, and cardiovascular diseases, often related from these workers[4]. In respect to the latter, evidences suggest that the circadian rhythm and the inherent rhythm of working activities are determinants of blood pressure (BP), and thus, shift working and fixed nighttime work provides a suitable environment for the study of the effect of circadian sleep /activity cycles on the twenty-four hour blood pressure profile[5].

Adding to all this internal modifications, additional external factors may add negatively to the adjustment of these individuals to this laboring schedules, such as family harmony, household chores or the noises that end interfering in the sleeping periods. Not to mention the fact that, with this working regime, poor food practices, tobacco consumption, coffee and drugs are also common and contribute negatively to the individual health.

1.2 Circadian rhythm and its physiology

The circadian rhythm (CR), which designates the pattern that organic functions follow during 24 hours, is directly related to several environmental variables such as temperature, humidity and luminosity[6]. These vary cyclically, and for the organism survival under the best conditions, it is important that physiological and behavioural processes are expressed in a rhythmic and synchronized manner with environmental cycles[2]. This biological clock is regulated by the suprachiasmatic nucleus, located in the brain[7], which, through the retino-hypothalamic tract, receives information from a photopigment found in the photoreceptors of the retina, the melanopsin[8]. When it receives this information about the external luminosity, this nucleus sends a signal by the upper cervical ganglion to the pineal gland that, in response to the luminosity, prevents the production of melatonin. Already in the presence of a dark environment and with few or any external stimulus, the gland signals the secretion of melatonin[9].

1.3 Melatonin and cortisol in the regulation of sleep and the circadian rhythm of BP

Melatonin, among many other functions, acts on sleep induction, insulin production, has antioxidant properties and acts on energy metabolism[10]. Thus, the increase in its production in the absence of light leads to adaptations such as slowing down and decreasing the physiological parameters of the organism (slower cardiac and respiratory rate, decrease alertness and wakefulness, lower body temperature and BP). It increases to a certain plateau during the sleep phase and decreases again with wake-up. Further, during awakening, and opposing to the decrease of the melatonin, there’s an increase in cortisol, a corticosteroid hormone, also known as "stress hormone," produced by the adrenal gland and regulated by the circadian rhythm[11,12]. I opposition to melatonin, cortisol prepares the body for physical and cognitive activity, being associated with marked changes in cardiovascular function and in the metabolism of carbohydrates and proteins[13].

Basal cortisol levels in the blood are higher in the morning, particularly during the awakening period, and slowly and gradually decrease along of day, until they reach their minimum during the evening, signaling the organism that should decrease its activity and thus allowing a collaboration with melatonin[11,12]. In stressful situations, cortisol activates the body's responses to emergency actions, promoting even greater and acute physiological adaptations. In situations of repetitive and prolonged exposure to stress the hormonal homeostasis may be disrupted leading to an overload of stress hormones, and a state of chronic sympathetic activation[13]. Therefore the chronobiological cycles are related to the balance between melatonin and cortisol, explaining the variation is several physiological parameters suche as BP and heart rate, both decreasing during the sleeping (night and siesta) period and increasing during the activity (day) period[3].

1.4 Effect of night work in melatonin and cortisol secretion

Understanding the physiological regulation of melatonin and cortisol in normal circumstances, and its dependence on luminosity, assists in the understanding the existence of important adaptations as a function of the working schedules, particularly whenever night-time labor is considered. It’s expected that a night-time worker, being exposed to light and to various external stimuli (light, noise, ...) at night and sleeping during the day, will experience hormonal and overall physiological adaptations [14,15], that are related to the common finding of non-repairing sleep, exhaustion and high BP. In addition to the fact that poor production of melatonin implies changes in the most diverse physiological and psychological aspects, such as the sleep cycle, and that the pattern of cortisol secretion is also altered, some studies have suggested that nocturnal workers have higher BP during the sleep period and are more prone to develop sustained arterial hypertension(AH)[15]. High blood pressure is a major public health problem, with an estimated prevalence above 25% worldwide, which is expected to dramatically increase in the next decade [16]. AH is an important risk factor for cardiac and cerebrovascular events[17], and could contribute to a 40% higher risk of cardiovascular diseases in night workers[18].

1.5 Physiological adaptation to night work

Night work imposes physiological adaptations to the body, which efficacy, size and speed are dependent on several factors, such as the individual's age, sleep habits, type of work, personality, physiological conditions and duration of exposure[19]. The longer the exposure duration, the easier the resynchronization will be. For shift workers, there’s a continuous need for physiological adaptation, creating greater physiological unbalances which may impair, not just organic aspects, but also social and cultural dimensions, as the body strives for biological rhythm adjustments whilst maintaining the usual daily activities beyond the working environment. With the inversion of the sleep/wake cycle, a chronological imbalance will occur, but the rhythm of the necessary adaptations isn’t uniform, and therefore the challenges to the organism well-being are increased, increasing the risk for maladaptation to nocturnal activity[20]. In certain aspects, the chronobiological cycles do not fully reverse, rather they are slightly attenuated, as is the case of BP, which is only partially inverted[5]. Some individuals never reach a situation of relative balance of their biological cycles and begin to reveal a specific set of nonspecific symptoms that lead to the diagnosis of bad adaptation syndrome in shift work[5]. Further, the challenges of chronological adjustments tend to aggravate with ageing, as a function of lesser physiological flexibility to adapt[5]. Considering the aforesaid, the present study proposes to investigate the adaptations of the BP circadian rhythm in response to night work situations.

2 Methods

Participants were recruited from a logistics company of an international food distribution and s retail group, during the last trimester of 2017. From a total of 100 workers, 23 fixed night shift workers (working schedule: 00h to 08h) were enrolled to the study, 3 of them with medicated AH. Initially, all information relating to the purpose of the project and to the methods for data collection were transmitted and informed consent to participate was obtained. Ambulatory blood pressure monitoring (ABPM) was used to characterize the 24h BP profile. BP was measured non-invasively with an oscillometric monitor, programmed for multiple measurements with 30 minute intervals and for a 24h period. A cuff adjusted for arm diameter was positioned in the non-dominant arm, aligned with the brachial artery. Mean BP and heart rate for daytime, nighttime and the overall 24 hours were obtained. AH was defined as the presence of anti-hypertensive medication or mean of 24h BP >130/ 80mmHg, and/or mean wake BP >135/85mmHg and/or mean sleep BP >120mmHg/ 70mmHg, following the recommendations of the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC7)21.
On the other hand, the evaluation of the sleep BP profile allowed the classification of the dipping status, as an inverted dipper for a rise of BP during sleep, a non-dipper when BP fell between 0-10% during sleep, a dipper when it fell between 10-20%, and extreme dipper for drops greater than 20% in sleep BP, following the recommendations of the American Heart Association22. Body mass index (BMI) was calculated dividing weight by the squared height (weight/height2) and classified into four classes based on the World Health Organization reference values: a BMI of less than 19 kg/m2 corresponds to low weight, a BMI of 19,0-24.9 kg/m2 corresponds to normal weight, a BMI between 25.0-29.9 kg/m2 to overweight and a BMI greater than 30.0 kg/m2 to obesity. The ABPM was initiated at the beginning of the working schedule, and at the same time point, a questionnaire was filled with demographic and anthropometric information (age, gender, height, weight, BMI), lifestyle information (hours of sleep per day, caffeine consumption and risk factors), work information (activity time in this shift and workload) and other aspects relevant to the study. All the data obtained through the questionnaire and ABPM were compiled in a datasheet.

2.1 Statistical Analysis

The statistical analysis was performed using the IBM SPSS Statistics 24 program. Initially, a simple descriptive statistics of the variables for the total sample and groups (normotensive and hypertensive) were obtained. Quantitative variables were expressed as mean ± standard deviation and compared using the Student t test. The qualitative variables were expressed as absolute count and frequency, and compared using the chi-square and the Fisher's exact tests. The Spearman correlation coefficient was used to address the association of BP and cardiovascular risk factors. The statistical significance was set for a $p < 0.05$.

3 Results

Twenty-three individuals participated in the study, three of them medicated for AH. The remaining 20 referred normal BP, but the ABPM identified 2 participants with new (unknown) AH.

The participant's age ranged from 20 to 48 years, with a mean of 30.48±8.31 years. The normotensive group were younger than the hypertensive patients, although the difference in age was not statistically significant (p=0.138). Regarding gender, males accounted for 82.6% of the study population, and there were also no statistically significant differences between the two groups (table 1), despite the fact that all hypertensive individuals were males. In relation to BMI, the mean value found in normotensive individuals was 24.48±2.63 kg/m2 and in hypertensive patients, 26.89±5.41 kg/m2, but the difference wasn't statistically significance (Table 1). Relatively to the categorized BMI, for the whole sample, the percentages of workers with normal weight and overweight were similar and only a small percentage suffered from obesity, all of them with AH (p=0.017). The descriptive analysis of risk factors identified smoking as the more prevailing risk factor, followed by the family history of AH, dyslipidemia and diabetes. Statistical analysis of each factor with the two groups showed no significant differences (table 2). When questioned regarding the number of sleep hours, 10 (44%) reported sleeping between 4-6 hours, 12 (52%) between 6-8 hours and 1 (4%) more than 8 hours. No significant differences were observed regarding this variable between groups.

Table 1: *Characterization of the sample by age, gender, body mass index (BMI) and body mass index by categories.*

		Total (n=23)	**Normotensive** (n=18)	**Hypertensive** (n=5)	***p***
Age, years (mean±SD)		30,48±8,31	29,11±7,78	35,40±9,15	0,138
Gender	**Male,** n (%)	19 (82,6%)	14 (77,8%)	5 (100%)	0,539
	Female, n (%)	4 (17,4%)	4 (22,2%)	0 (0%)	
BMI, kg/m² (mean±SD)		25±3,42	24,48±2,63	26,89±5,41	0,384
BMI categories	**Normal weight**, n (%)	11 (47,8%)	9 (50%)	2 (40%)	0,017
	Overweight, n (%)	10 (43,5%)	9 (50%)	1 (20%)	

Table 2: *Presentation of risk factors for all workers and for the study groups (normotensives and hypertensives).*

Obesity, n (%)	2 (8,7%)	0 (0%)	2 (40%)

Variables expressed in number of individuals (n), and respective percentage (%), and mean±standard deviation (SD).

		Total n (%)	Normotensive n (%)	Hypertensive n (%)	*p*
Familiar history of high BP	Yes	10 (43,5%)	7 (38,9%)	3 (60%)	0,400
	No	13 (56,5%)	11 (61,1%)	2 (40%)	
Smoker	Yes	14 (60,9%)	10 (55,6%)	4 (80%)	0,322
	No	8 (39,1%)	1 (44,4%)	1 (20%)	
Cholesterol	Yes	4 (17,4%)	2 (11,1%)	2 (40%)	0,132
	No	19 (82,6%)	16 (89,9%)	3 (60%)	
Diabetes	Yes	1 (4,3%)	1 (5,6%)	0 (0%)	0,590
	No	22 (95,7%)	17 (94,4%)	5 (100%)	

Variables expressed in number of individuals (n) and respective percentage (%).

From the analysis of the correlations between all variables, and considering the most relevant variables for the purpose of the study, significant associations were depicted as follows (table 3): age with nocturnal mean diastolic BP (p=0.046); gender with mean 24h, daytime and nighttime systolic BP (p=0.001; p= 0.001 and p=0.019, respectively); obesity with mean 24h, daytime and nighttime systolic BP (p=0.046; p=0.040 and p=0.035, respectively), and with the diagnosis of AH (p=0.003). As to the historical duration of the nocturnal work, 39.1% referred working in such schedule for 6 months to 1 year, 34.8% for 1 to 6-month, 17.4% for 1 to 5 year, and 8.7% for less than 1 month.

Table 3: *Presentation of relevant variables that were found to be statistically significant.*

		BP systolic 24h	BP systolic diurnal	BP systolic nocturnal	*BP diastolic nocturnal*	*Diagnosis*
Age	ρ	-0,051	-0,007	0,090	0,421	0,272
	sig	0,816	0,974	0,682	0,046	0,209
Gender	ρ	-0,624	-0,624	-0,485	-0,104	-0,242
	sig	0,001	0,001	0,019	0,637	0,266
Obesity	ρ	0,420	0,431	0,442	0,350	0,586

	sig	0,046	0,040	0,035	0,102	0,003
Nocturnal activity time	ρ	-0,220	-0,288	-0,005	0,057	-0,403
	sig	0,314	0,183	0,983	0,796	0,056

Considering the mean ABPM values obtained for the all study population, all values are within normal range, including the reduction on sleep BP (table 4 and figure 1), notwithstanding the 2 participants with new AH. In addition, only 1 (4.3%) participant was classified as an inverted-dipper. Of the remainder, 6 (26.1%) were classified as non-dippers, 15 (65.2%) as dippers and 1 (4.3%) as extreme dipper.

Table 4: *Presentation of the parameters obtained with ABPM for the total sample.*

Parameters obtained	**mean±SD**	
	Systolic	**Diastolic**
BP 24h, mmHg	122±11,949	72±8,679
BP diurnal, mmHg	127±12,112	76±8,845
BP nocturnal, mmHg	112±11,087	62±8,711
Systolic night fall, %	11,35±6,853	

BP: blood pressure. Variables expressed as mean±standard deviation (DS).

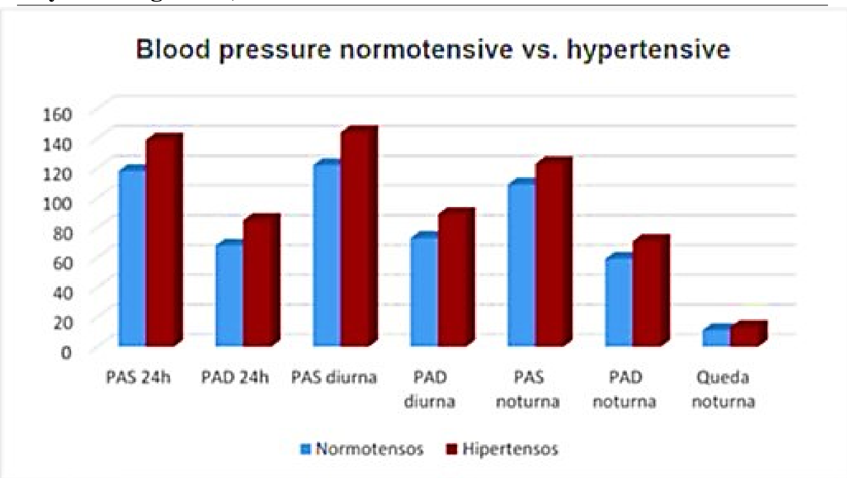

Figure 1: *Representation of averages bloods pressures (24h, diurnal and nocturnal) in the normotensives group and hypertensives group.*

The comparison between the 2 groups (normotensive and hypertensive) revealed higher mean BP values in the AH group, as expected.

ρ: spearman correlation coefficient
sig: statistical significance (p <0.05)

4 Discussion

The evaluation of the 24h BP profile allowed for the identification of the expected adaptation in the chronobiological rhythm of this hemodynamic parameter, with a fall in BP coinciding with the sleeping period, and higher BP occurring during the activity periods, which is in agreement with previous studies5. From the hour BP histograms (not presented) it was also possible to observe that the higher BP and the greater amount of BP variability were registered during the working hours (00h-08h), also as expected. With the approximation of the beginning of the following working period (next day), an increase in BP was also depicted, with the highest BP value coinciding with the first measurement performed at the beginning of the shift, at midnight, possibly translating into the white-coat effect. The hypothesis that age, gender, and risk factors such as smoking, diabetes, and cholesterol, could explain a lower sleep drop in systolic BP, was not confirmed. In addition, it was observed an increase in sleep mean diastolic BP with ageing, which is in accordance with previous studies, notwithstanding the fact that significant relations have been shown also with the other BP variables, and such wasn't observed in the present study although, contrary to the present study[23].
Statistical analysis revealed higher systolic BP in males and in the obese individuals, thus indicating that gender is a major determinant of BP, and also that the overweight and obesity constitute a major contributor do high BP values, in accordance to previous research[24].
Also, it was possible to identify an association of BP with the history of night working, suggesting that the more recent workers are those who have highest BPs, which could translate into a time dependence for the necessary physiological adjustments to occur and to resynchronize the body to the professional context, taking into account that only 4 workers work for over 1 year in night activity.

5 Conclusion

In conclusion, the present study demonstrated that the circadian rhythm of BP is adapted as a consequence of permanent nocturnal work, which indicates a physiological adaptation of the organism to fixed nocturnal exposure, independently of sociodemographic characteristics, risk factors or other external factors included in the analysis. In addition, age, male gender, obesity, and those working less time in night schedules were associated with higher BP.

Future researches

In order to solidly objectify the physiological adaptation that occurs in workers, and even to quantify the inversion observed in this study, we suggest continuing the study in a larger sample, contributing to the increase knowledge of occupational hazards and safety.

Study limitations

As limitations to the study, the ABPM method is known to affect the quality of sleep, so the sleep BP reduction might be underestimated. The small number of participants limited the statistical power of the study, and therefore caution is advised considering the extrapolation of the results.

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