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Overweight Impairs Postural Control of Female Night Workers

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Abstract

Objectives To verify the relationships between sleep duration (Total Sleep Time – TST) and postural control of female night workers before and after shift. As well as, to verify if there is an influence of the body mass index (BMI) on the postural control of these female workers before and after shift.

Methods A total of 14 female night workers (mean age: 35.0 ± 7.7 years) were evaluated. An actigraph was placed on the wrist to evaluate the sleep-wake cycle. The body mass and height were measured, and BMI was calculated. Postural control was evaluated by means of a force platform, with eyes opened and eyes closed before and after the 12-hour workday.

Results There was an effect of the BMI on the velocity and the center of pressure path with eyes opened before ($t = 2.55$, $p = 0.02$) and after ($t = 4.10$, $p < 0.01$) night work. The BMI impaired the velocity and the center of pressure path with eyes closed before ($t = 3.05$, $p = 0.01$; $t = 3.04$, $p = 0.01$) and after ($t = 2.95$, $p = 0.01$; $t = 2.94$, $p = 0.01$) night work. Furthermore, high BMI is associated with female workers' postural sway ($p < 0.05$).

Conclusion Therefore, high BMI impairs the postural control of female night workers, indicating postural instability before and after night work.

Keywords
- circadian rhythms
- postural balance
- shift work schedule

Introduction

Obesity, sleep deprivation, night work, chronic diseases and their consequences have been discussed in several areas and international bodies in order to search solutions and instruments to combat or prevent these problems related to public health. Shift workers, for example, are a population susceptible to developing sensorimotor, metabolic, endocrine disorders and, consequently, chronic diseases associated with sleep debit.[1–3]

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Overweight, obesity, dyslipidemias, and cardiovascular diseases due to sleep debit prevalent among night workers have been commonly reported in several studies.[1,4,5] The high body mass index (BMI) in the Norwegian population has been associated with short sleep durations (≤ 5 to 7 hours) during working days.[6] Mota et al. reported low sleep quality, overweight, obesity, and prevalence of sleepiness among Brazilian resident doctors who worked 12-hour shifts.[1] Other studies have observed high prevalence rates of overweight (62.4–69.5%) and obesity (15.7–30.0%) among shift workers.[7,8] Da Silva et al. found a prevalence of 30% of obesity in Brazilian female shift-workers.[9] Another study revealed that there was a 12% increased risk of obesity in female night work nurses compared with nurses working other shifts, and the possible explanations for this finding are sleep deprivation, inadequate eating habits, and lower light exposure.[10]

European studies have shown that longer exposure to shift work was associated with obesity, dyslipidaemia, hyperglycaemia, and hypertension.[2,5] These bodily changes in workers can be explained by several factors, such as inadequate nutrition, sleep debt and/or sleep deprivation, as well as the result of desynchronization of the biological rhythm.[11–13] Desynchronization of the biological rhythm due to constant shift rotations, in addition to the sleep restriction by 2 to 4 hours, are triggering factors for an increased body weight, an elevation of the levels of the hormone ghrelin, as well as a reduction of the levels of the hormone leptin; both of these hormones are involved in the endocrine regulation of appetite and satiety, thus causing long-term nutritional and energy imbalances.[14,15] As a result of these endocrine, metabolic, and behavioral changes experienced by male and female shift-workers, there is a prevalence of sedentary lifestyle,[5,11,16] increased sleepiness, and reduced psychomotor and postural performance.[7,17,18]

In addition to the above information, overweight and obesity are also related to certain structural modifications in the body that can trigger important mechanical limitations on the ability to perform common daily activities.[19,20] In this population, a reduction on postural stability in sports activities and even simple or functional tasks of daily living, such as locomotion, can cause discomfort, risk of falls, and injuries.[19,21–23] A decrease of the postural stability in obese persons could impair the activities of daily living and cause greater risk of falling.[22] Menegoni et al. found the biomechanical alterations on postural sway of obese individuals.[24] The high body weight impaired the anteroposterior center of pressure (AP CoP) stability in both genders (n = 22 male and 22 female); however, the women's body weight was directly correlated with increased center of pressure (CoP) and AP CoP velocity parameters, resulting in poor postural stabilization.

Recent studies have reported negative impact of the body mass distribution, poor muscle strength and the high BMI (overweight and obesity) on postural sway of the males and females.[25–28] The female fat mass is distributed around the hips and the upper legs (gynoid shape), and the fat male mass concentrate in the thorax-abdominal region (android shape). Therefore, the body mass distribution shows differences between the gender and it alters the center of mass (CoM) position, increasing the anteroposterior (AP) and mediolateral (ML) CoP sway.[24] However, the difference in CoP sway between the obese male and female there is no consensus and could be more investigated.

Increased body mass in the trunk and upper limbs associated with changes in the mechanoreceptors of the lower limbs, along with muscle weakness and/or fatigue, especially of the postural muscles,[29,30] may trigger an increase in postural sway and difficulties in standing.[19,25] A study with 41 female shift-workers demonstrated the decline of the postural control by 13.8% after the shift as result of fatigue,[31] and another study revealed worse shift-workers' postural performance due to muscle fatigue.[32] Therefore, it is possible to observe cognitive and motor deficits as a consequence of obesity, fatigue, and nocturnal sleep deprivation.

The objectives of this study were: 1. To verify the relationships between sleep duration (TST) and postural control of female night workers before and after shift; and 2. To verify if there is an influence of the BMI on the postural control of these female workers before and after shift. On the basis of the literature, we hypothesized that high BMI and sleep restriction impact on the female night workers' postural control.

Material and Methods

The present cross-sectional study was submitted to the Committee on Ethics and Research on Human Beings of the Federal University of São Paulo and obtained approval under number 195.746/2013. After the participants were informed of the purpose and procedures of the study, they signed an informed consent form (ICF). In addition, the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines has been consulted and verified throughout the text.[33,34]

Study Population

A total of 36 female night workers from a Brazilian philanthropic company in the city of São Paulo, SP, were recruited to participate of the study from polysomnography (PSG) departments of this company. Thereby, it is a convenience sample. Participants were excluded if they worked a double shift; napped off or slept during the night shift; drank alcohol and/or used psychoactive drugs 24 hours prior to the evaluations; presented some symptom of sleep disorders or sleep complaints (insomnia, snoring, sleep apnoea etc.); had auditory and visual impairments; had undergone limb amputations; used a prosthesis; could not walk; used a wheelchair; and did not use the actigraph correctly.

Overall, 22 female night-workers were not included in the study: 8 female workers were not able to perform all the evaluations, 7 worked a double shift, 2 napped during the night work on evaluation days and 5 had sleep complaints. Thus, the study sample consisted of 14 PSG technicians who had worked ≥ 1 year on the night shift on a fixed schedule of 12-hours night shift by 36-hours off (12 × 36 h). A post hoc analysis was performed using the G*Power (Heinrich Heine

Table 1 Schedule for study evaluation days.

Evaluation day	Time (hour)	Activities (evaluations)
First day	19:00	Filled out the individual identification form and the ICF Measurement of body mass and height Wore the actigraph on the nondominant wrist Receipt of the sleep diary
Second to the fifth day	–	Use the actigraph and filled out the sleep diary
Sixth day	19:00–19:50	Postural control (preshift) evaluations
Seventh day	08:10–09:00	Postural control (postshift) evaluations Delivery of the actigraph and the sleep diary to the researcher responsible

Abbreviation: ICF, informed consent form.

University, Düsseldorf, NRW, Germany) software, version 3.1.92, and a sample size of 14 achieved 76% power; the correlation coefficient between the two variables was 0.59, with a level of significance of 0.05.

Procedures

The participants were evaluated for 7 days, as shown in ►**Table 1**. The evaluations of the last 2 days (sixth and seventh) occurred before (after 36 hours off: post day off) and after (immediately after the end of the night shift) the night shift at the Centro de Estudos em Psicobiologia e Exercício (CEPE), in the same building of the workplace of the participants, in the city of São Paulo.

Participants wore only the actigraph on the nondominant wrist for 7 days of evaluation and completed the sleep diary with general information on activity and rest. Body mass and height were measured on the first day of evaluation, and BMI was calculated to verify the nutritional status of the participants. The BMI (kg/m^2) was obtained by dividing the body mass (kilograms) by the square of the height (meters). For categorization, the classification recommended by the World Health Organization (WHO)[35] was used: underweight ($<18.5\,kg/m^2$), normal weight ($18.5–24.9\,kg/m^2$), overweight ($25.0–29.9\,kg/m^2$), and obese ($\geq 30\,kg/m^2$).

Anthropometric Data

Body mass and height were measured in a quiet, reserved room. To measure body mass, we used a Filizola (Filizola, São Paulo, SP, Brazil) anthropometric scale and a stadiometer of the same brand attached to this scale. The participants were asked to remove their personal objects of the body and/or of the clothing (watch, mobile phone, wallet etc.) and to remain in an orthostatic position, barefoot, and with arms relaxed at the body sides.

Actigraph and Sleep Diary

To measure the sleep duration (Total Sleep Time – TST), the sleep efficiency (ratio of total sleep time to time in bed) and the presence or absence of naps during the night work, a Sleepwatch actigraph was used (Ambulatory Monitoring Inc, Ardsley, NY, USA) containing a piezoelectric accelerometer that records activity-rest or sleep-wake cycle by means of the body movements. Recent studies have demonstrated a moderate to high agreement of actigraphy to the polysomnography (50–96%).[36,37] Marino et al.[37] reported high accuracy (0.863) and high sensitivity (0.965) when comparing the concordance between both instruments. Therefore, the actigraphy provides reliable records of sleep parameters and demonstrates results relevant to circadian rhythm disorders in shift workers.[38,39] For the evaluations, the actigraph was placed on the nondominant wrist of the participants on the first day of evaluation, and it remained on the wrist until the end of the evaluations (seventh day). Participants were instructed on how to use the actigraph as follows: when going to bed, upon waking up, removing, and replacing the actigraph on the wrist, participants should press the event marker button to record these activities. In addition, a sleep diary was used to record sleep-wake activities. The collected data were transferred to a computer and analyzed using ActionW (Ambulatory Monitoring Inc., Ardsley, NY, USA) software, version 2.

Postural Control

Postural control was measured by means of a OR6 AMTI force platform (AMTI, Watertown, MA, USA) to obtain the reaction forces and to estimate the center of pressure.[40] To obtain postural stability results, it is necessary to maintain the center of mass (CoM) within the base of support and integration between the motor, neural and sensorial systems.[40–42]

Participants stood in bipedal support on the force platform for 30 seconds under eyes opened and eyes closed conditions in a quiet room. The feet remained approximately shoulder-width apart, and the upper limbs were relaxed at the body sides. Two tests were performed in duplicate (twice each condition), with an interval of 1 minute between them. With their eyes closed, a black blindfold or cap was placed over the eyes of the participants to produce total absence of vision, and in the eyes opened condition, the participant was asked to keep her gaze fixed on a black, 5-centimetre diameter target positioned at eye level against a white wall. In both condition the participants remained at a distance of two (2.0) meters of the target at the wall. The reaction force and moments of force coming from the force platform were acquired by a NI BNC-2090 acquisition card (National Instruments Inc., Austin, TX, USA) at a frequency of 100 Hz, using the LabVIEW (National Instruments Inc., Austin, TX, USA) software. Subsequently, center of pressure (CoP) values in both the anteroposterior and mid-lateral directions were estimated and filtered (Butterworth low pass digital filter, second order and 5 Hz cut off frequency). Finally, the mean CoP velocities for anteroposterior and mediolateral sway (Vel_{ap}; Vel_{ml}), the total velocity (Vel_{total}) and the anteroposterior and mediolateral CoP Path ($Cpath_{ap}$; $Cpath_{ml}$) were calculated. Both the cut off frequency filter and the variables definition were based on previous studies.[43,44] All of these procedures were performed using specific routines written with MATLAB software (MathWorks, Natick, MA, USA).[7]

Statistical Analysis

The paired-samples *t*-test was used to compare the parameters of the postural control (Vel_{ap}, Vel_{ml}, Vel_{total} of the COP, $Cpath_{ap}$ and $Cpath_{ml}$) before and after the night work. The Pearson correlation coefficient was estimated to evaluate the correlation between the following variables: BMI versus postural control, and TST versus postural control. Subsequently, a linear regression test was performed the effect of BMI on postural control, and it was used the stepwise method. BMI was considered the independent variable, and postural control parameters were considered the dependent variables. The significance level considered was 5% ($p < 0.05$).

Results

The study sample consisted of 14 sedentary and overweight women according to the WHO classification (►**Table 2**). The sleep efficiency was within the normality parameters (sleep efficiency > 85%)[45]; however, the TST mean before the night work was 259.9 ± 67.5 min or 4 hours and 33 minutes. (►**Table 2**). Additionally, ►**Table 2** shows the mean age of the night workers and the working night-time.

Table 2 Participants' characteristics related to age, sex, nutritional status, working nighttime and sleep variables (n = 14).

	Night workers (Mean ± SD; %)
Age (years)	35.0 ± 7.7
Female sex (%)	100%
BMI (kg/m^2)	27.4 ± 2.8
Working nighttime (years)	3.0 ± 1.9
TST (minutes)	259.9 ± 67.5
Sleep efficiency (%)	98.3 ± 1.4

Abbreviations: BMI, body mass index; TST, total sleep time. **Notes:** Values presented as mean ± SD (standard deviation [SD]) and percentage (%).

The postural control parameters presented similar means before and after the night work (►**Table 3**). Although not significant, with their eyes open the parameters increased after the shift: Vel_{ap} (3.3%), Vel_{total} (2.5%) and $Cpath_{ap}$ (4.0%). When with their eyes closed, although not significant, these parameters were reduced after the night work, except in the mediolateral direction (►**Table 3**).

We found positive correlations between BMI and the postural control ($Vel_{ap,}$ Vel_{total} of the CoP, and $Cpath_{ap}$) in the eyes opened (►**Table 4**) and eyes closed (►**Table 5**) conditions, before and after the night work. These results demonstrated that high BMI (overweight/obesity) is strongly associated with postural sway: when BMI increases, the postural sway of these night workers increases. However, there was no correlation between TST and postural control parameters in either direction (anteroposterior and

Table 3 Participants' postural control parameters before and after night work (n = 14).

Parameters	Before shift Mean ± SD	95% CI	After shift Mean ± SD	95% CI	Effect size	Delta (%)	*p*-value
Postural control: Eyes opened							
Vel_{ap} (cm/s)	0.61 ± 0.25	0.5; 0.76	0.63 ± 0.26	0.53; 0.79	0.08	3.3%	0.370
Vel_{ml} (cm/s)	0.37 ± 0.14	0.3; 0.44	0.37 ± 0.08	0.32; 0.41	0.00	0.0%	0.986
Vel_{total} (cm/s)	0.79 ± 0.3	0.65; 0.96	0.81 ± 0.24	0.72; 0.96	0.07	2.5%	0.591
$Cpath_{ap}$ (cm)	18.36 ± 7.62	14.93; 22.73	19.1 ± 7.74	15.86; 23.76	0.10	4.0%	0.363
$Cpath_{ml}$ (cm)	11.01 ± 4.16	8.97; 13.22	11.0 ± 2.41	9.76; 12.24	0.00	−0.1%	0.988
Postural control: Eyes closed							
Vel_{ap} (cm/s)	0.8 ± 0.36	0.63; 1.00	0.75 ± 0.27	0.63; 0.91	0.16	−6.3%	0.340
Vel_{ml} (cm/s)	0.42 ± 0.14	0.35; 0.49	0.44 ± 0.11	0.39; 0.49	0.16	4.8%	0.475
Vel_{total} (cm/s)	0.98 ± 0.38	0.81; 1.20	0.96 ± 0.25	0.85; 1.11	0.06	−2.0%	0.742
$Cpath_{ap}$ (cm)	23.96 ± 10.87	19.04; 29.96	22.48 ± 8.0	19.01; 27.21	0.16	−6.2%	0.348
$Cpath_{ml}$ (cm)	12.49 ± 4.09	10.55; 14.73	13.36 ± 3.24	11.76; 14.86	0.24	7.0%	0.476

Abbreviations: CI, confidence interval; SD, standard deviation; Vel_{ap}, anteroposterior velocity; Vel_{ml}, mediolateral velocity; Vel_{total}, total velocity; $Cpath_{ap}$, anteroposterior COP path; $Cpath_{ml}$, mediolateral COP Path. **Notes:** Values presented as mean ± SD and 95% CI.

Table 4 Correlation coefficients (*r*) of TST and BMI for the parameters related to postural control – eyes opened (n = 14).

Postural control: Eyes opened	Correlation	TST (minutes)	BMI (kg/m^2)
Before shift			
$Vel_{ap\ (cm/s)}$	*r* *p*	−0.068 0.818	**0.593** 0.025*
$Vel_{ml\ (cm/s)}$	*r* *p*	0.091 0.756	0.341 0.233
$Vel_{total\ (cm/s)}$	*r* *p*	−0.027 0.926	**0.543** 0.045*
$Cpath_{ap\ (cm)}$	*r* *p*	−0.068 0.816	**0.593** 0.025*
$Cpath_{ml\ (cm)}$	*r* *p*	0.087 0.768	0.341 0.233
After shift			
$Vel_{ap\ (cm/s)}$	*r* *p*	0.081 0.784	**0.764** 0.001*
$Vel_{ml\ (cm/s)}$	*r* *p*	0.014 0.963	−0.209 0.473
$Vel_{total\ (cm/s)}$	*r* *p*	0.086 0.770	**0.678** 0.008*
$Cpath_{ap\ (cm)}$	*r* *p*	0.080 0.785	**0.764** 0.001*
$Cpath_{ml\ (cm)}$	*r* *p*	0.013 0.966	−0.208 0.475

Abbreviations: BMI, body mass index; TST, total sleep time; Vel_{ap}, anteroposterior velocity; Vel_{ml}, mediolateral velocity; Vel_{total}, total velocity; $Cpath_{ap}$, anteroposterior COP path; $Cpath_{ml}$, mediolateral COP Path. **Notes:** *Significant difference after correlation of the variables ($p < 0.05$) using the Pearson correlation coefficient.

Table 5 Correlation coefficients (*r*) of TST and BMI for the parameters related to postural control – eyes closed (n = 14).

Postural control: Eyes closed	Correlation	TST (minutes)	BMI (kg/m^2)
Before shift			
$Vel_{ap\ (cm/s)}$	*r* *p*	−0.124 0.672	**0.660** 0.010*
$Vel_{ml\ (cm/s)}$	*r* *p*	−0.260 0.369	0.287 0.321
$Vel_{total\ (cm/s)}$	*r* *p*	−0.173 0.554	**0.613** 0.020*
$Cpath_{ap\ (cm)}$	*r* *p*	−0.127 0.664	**0.660** 0.010*
$Cpath_{ml\ (cm)}$	*r* *p*	−0.267 0.356	0.286 0.322
After shift			
$Vel_{ap\ (cm/s)}$	*r* *p*	0.087 0.768	**0.648** 0.012*
$Vel_{ml\ (cm/s)}$	*r* *p*	0.211 0.468	−0.300 0.297
$Vel_{total\ (cm/s)}$	*r* *p*	0.154 0.599	**0.536** 0.048*
$Cpath_{ap\ (cm)}$	*r* *p*	0.089 0.763	**0.648** 0.012*
$Cpath_{ml\ (cm)}$	*r* *p*	0.223 0.444	−0.297 0.302

Abbreviations: BMI, body mass index; TST, total sleep time; Vel_{ap}, anteroposterior velocity; Vel_{ml}, mediolateral velocity; Vel_{total}, total velocity; $Cpath_{ap}$, anteroposterior COP path; $Cpath_{ml}$, mediolateral COP Path. **Notes:** *Significant difference after correlation of the variables ($p < 0.05$) using the Pearson correlation coefficient.

mediolateral) or between BMI and postural control parameters in the mediolateral direction.

Linear regression analysis showed that high BMI influenced the postural control of night workers before and after the night work. The postural control parameters in the eyes opened and eyes closed conditions influenced by overweight were showed on the ►**Table 6**. Thus, for each increase in BMI value, there is a significant increase in the postural sway (Vel_{ap}, Vel_{total} of the COP, and $Cpath_{ap}$) of female workers who are deprived of night sleep on workdays.

Discussion

The present study investigated anthropometric, behavioral, and sensorimotor integration variables in female night workers. According to the results, the TST of the female night workers was < 5 hours. If we consider this amount of sleep, the sample of the study presented a short sleep duration, which may reinforce the detrimental effects of the inversion of the sleep-wake cycle on workdays. Researchers revealed that sleeping between 5 and 5.9 hours increases the chance of occupational injury risk (odds ratio [OR] = 1.79), thereby compromising workers' safety[46] and health.[2,10,47] Yoon et al.[47] showed that working <40 or >60 hours per week is associated with obesity in female Korean workers. The type of work was associated with obesity in nonmanual workers (OR = 1.20), and manual workers who work >60 hours had a higher likelihood of obesity (OR = 1.10).

In addition, shift work per se and sleep duration < 7 hours are associated with body weight gain, obesity, cardiovascular and metabolic diseases,[8,13,48] performance losses, fatigue, postural instability, and increased risk of accidents.[13,48] Further on the health problems and damages mentioned, Ma et al.[49] reported that prolonged wakefulness or sleep deprivation impairs information from the somatosensory, visual and vestibular systems that control the postural stability,[49] thus impairing daily activities that require balance and postural control. The shift-working time induced postural instability in nurses worked three 12-hour shifts in a 4-day period.[31]

In this sense, in several clinical studies, high BMI, sleep deprivation and sleepiness symptoms were related to a decline in postural performance.[3,7,25] In the present study, we observed an association between high BMI (27.4 ± 2.8 kg/m^2) and postural sway in the anteroposterior direction before and after the night shift. The anteroposterior velocity and the total velocity of CoP as well as the CoPpath increased in magnitude, representing greater difficulty in keeping the

Table 6 Association coefficients (R^2) of postural control parameters with eyes opened and eyes closed of the female workers before and after night shift (n = 14).

Postural Control parameters			Vel_{ap}	$Cpath_{ap}$	Vel_{total}
Before night shift	**Eyes opened**	R^2	0.352	0.352	0.295
		β	0.05	1.62	0.06
		95% CI	0.01–0.10	0.24–3.00	0.01–0.11
		t	2.55*	2.55*	2.24*
	Eyes closed	R^2	0.436	0.435	0.376
		β	0.09	2.57	0.08
		95% CI	0.0–0.14	0.73–4.41	0.02–0.15
		t	3.05**	3.04**	2.69*
After night shift	**Eyes opened**	R^2	0.583	0.583	0.460
		β	0.07	2.12	0.06
		95% CI	0.03–0.10	0.99–3.24	0.02–0.10
		t	4.10***	4.10***	3.20***
	Eyes closed	R^2	0.420	0.419	0.288
		β	0.06	1.86	0.05
		95% CI	0.02–0.11	0.48–3.23	0.01–0.10
		t	2.95**	2.94**	2.20*

Abbreviations: CI, confidence interval; Vel_{ap}, anteroposterior velocity; Vel_{total}, total velocity; $Cpath_{ap}$, anteroposterior COP path. **Notes:** Linear regression analysis; $^{*}p < 0.05$; $^{**}p = 0.01$; $^{***}p < 0.01$.

CoM stable and the body in postural balance within the support base.[22] In summary, our sample (female night workers) showed association between higher BMI (overweight) and greater postural sway.

Thus, female night workers with high body mass also had a decreased postural performance, regardless of working hours, sleep duration, and sensory inputs (eyes open or closed). With this information, it is possible to suggest that female workers of this study may be predisposed to falls and, consequently, injuries in the work environment.[23,28,31] In agreement with our study, researchers showed that high BMIs interfere with postural stability, which may compromise the control of posture in obese and overweight individuals.[25,26,50] Hue et al.[25] reported that regardless of sensory inputs (with or without vision), CoP velocity increased linearly with increasing body mass, indicating a reduction in postural performance due to obesity. In the study by Teasdale et al.,[22] the loss of body weight through diet and exercise reduced the CoP velocity, contributing to the increase in postural stability. Thus, these studies with different populations have demonstrated the incidence of postural instability associated with overweight or obesity, which makes this situation one of concern for the entire public health system. In contrast to most studies, Blaszczyk et al.[51] and Pajoutan et al.[52] reported that obese individuals evaluated on a force platform showed less CoP oscillation than nonobese individuals. However, Handrigan et al.[53] commented, in a letter to the editor, that they disagree with the results of Blaszczyk et al.[51] Likewise, Tanwar et al. (2021)[54] demonstrated that in a group of the university students (males and females) with "poor" sleep quality (global PSQI score ≥ 5), this factor was associated with a deterioration of postural control but not with BMI.

Other authors have reported that as a result of the reduction of plantar somatosensory responses, obese people may restrict postural sway as a compensation strategy to remain within their support base.[52,55] After a night shift, this compensation strategy may have used by the women in our sample, because of the results showed reduction of the CoP Vel_{ap},Vel_{total}, and $Cpath_{ap}$ parameters in the eyes closed condition in the anteroposterior direction, although not significant (►**Table 3**: Delta %; *p*-value).

There are some theories that explain the relationship between overweight/obesity and postural instability. One theory is that overweight and/or obesity can alter the relative body orientation; therefore, a redistribution of the body mass to the upper (abdominal) region occurs, contributing to the CoM anteriorization on the support base. This anterior change in CoM increases anteroposterior sway,[22,27,56] the direction most affected in the present study. The mediolateral direction of the CoP in this study was not associated with BMI due to the possibility that obese women widen their support base to remain stable as a consequence of the accumulation of adipose tissue in the lower limbs, especially in the thighs and hip.[51] On the other hand, there is evidence that the anteroposterior oscillation in the upright posture is maintained mainly by the muscular system of the ankle.[57,58] Studies have shown that obese individuals do not generate enough muscular strength in the ankle region to remain stable in their support base and avoid falling.[19,24] Studies with different populations have shown that the reduction of sensory stimuli or impairments of the visual, vestibular, and mechanoreceptor systems increase postural sway.[41,49,59] For example, neuromuscular and sensitivity changes in the lower limbs of obese individuals may contribute to postural instability.[21,60]

Another theory revealed that obese individuals exhibit reduced cutaneous sensitivity of the feet, especially of mechanoreceptors, also contributing to the inefficiency of their postural control.[19,25] A systematic review showed the obesity was associated with lower plantar sensitivity and increased postural instability in a sample of adult women.[28]

In the results of Wu and Madigan,[21] there was an increase in the postural sway of obese university students (14 female and 6 male) due to the reductions in plantar sensitivity and muscle strength. However, the present study did not measure the sensory efficiency of the night workers' lower limbs, which can be considered as a limitation of the study.

Previous studies have reported that the sedentary lifestyle and the reduced efficiency of the lower limb proprioceptive system, with consequent decreases in muscle strength and muscle trophism, may interfere with motor control, especially postural performance.[30,61]

Based on these observations, the short- and long-term body mass gains associated with the inversion of the sleep-wake cycle in these overweight female night workers revealed motor and functional damage. From the practical point of view, although not significant (*p*-value), our sample of female night workers had an increased postural sway in the eyes opened condition after night work (Delta [%]: $Vel_{ap} = 3.3$; $Vel_{total} = 2.5$, $Cpath_{ap} = 4.0$), which can trigger incidents or accidents during work and/or upon returning home. Thus, it was possible to observe an impairment of the postural system related to the increase in body mass and not only to nocturnal sleep deprivation. It is a fact that sleep deprivation and night work *per se* affect metabolism and worsen postural control;[3,7] therefore, it is important to note that, in addition to the effects of night work on sleep deprivation, obese or overweight workers are more susceptible to falls, injuries,[23] accidents, and associated chronic diseases. Studies have shown that postural control and body mass gain are multifactorial and that both depend on neurophysiological and endocrine responses. Any metabolic dysfunction and changes in sensory and neuromotor systems can affect postural control.[21,42,60]

Issues related to metabolic, motor and postural changes are highly relevant in our 24-hour society, as a growing amount of scientific evidence clearly shows that sleep deprivation and night work are closely related to workers' health, psychomotricity, and quality of life.[4,16] Therefore, it is imperative to inform workers, especially female shift workers, about the relationship between metabolic and postural changes, as well as to implement methods of assessment and intervention in companies/industries/institutions to prevent fatigue, possible occupational accidents, and chronic diseases related to work.

In relation to the above findings, a substantial reduction of postural control can be determined by metabolic alterations due nocturnal sleep deprivation and/or by occupational activities that require high postural demands, which, consequently, cause fatigue in the trunk and lower limbs.

The presence of only women in the study sample (100%), the sample size, and the absence of control group may limit the generalization of the results. The lack of measurement of the lower limbs' muscular strength and fatigue symptoms of the female night workers were another limitation of the study. Therefore, we believe that more studies of motor control in the workplace (in loco) are necessary to confirm this relationship between metabolic and postural dysfunctions in workers who are deprived of nights' sleep.

Conclusions

The present study revealed an association between overweight and postural sway before and after a 12-hour night work, indicating worsening of the postural control of female night workers with high BMIs. On the other hand, there was no correlation between TST and postural control parameters of the female night workers in the present study.

Conflict of Interests
The authors have no conflicts of interest to declare.

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