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Evaluating Dynamic Stability, Spatiotemporal, and Kinematic Gait Parameters in Day- and Night-Shift Nurses

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ABSTRACT

Background: Despite the importance of investigating the effect of night shifts on the gait kinematics of nurses, the literature lacks sufficient evidence to evaluate this relationship. Therefore, the present study aimed to compare gait kinematics between day and night shift nurses.

Methods: Participants (N = 31) in this cross-sectional study were female nurses aged 27–47 years, working either night shifts (N = 16) or day shifts (N = 15). A Qualisys motion analysis system with eight high-speed cameras was used to record body segment movements during walking. The spatiotemporal gait characteristics (stride length, walking velocity, and cadence) and kinematics of the ankle, knee, hip, pelvis, and trunk were analyzed. Dynamic stability during walking was assessed by measuring center of mass (COM) movements.

Results: No significant differences were found between the mean values of spatiotemporal gait parameters of nurses working day and night shifts. Similarly, the mean range of motion (ROM) values of lower extremity joints and pelvic and trunk segments during the stance phase of gait did not differ significantly between the two groups. However, as a measure of dynamic stability, COM movement in the mediolateral direction was significantly different between the groups.

Conclusion: There were no differences in spatiotemporal gait parameters, vertical dynamic stability, or joint ROM between nurses working day and night shifts. These findings suggest that working night shifts does not alter the biomechanical gait patterns of nurses.

Introduction

Nurses' health impairment affects their quality of life and compromises patient safety [1]. The nursing profession requires performing heavy workloads, lifting and transferring patients from beds, working in awkward postures, and spending substantial time standing or walking on concrete and hard surfaces [2-4]. Musculoskeletal disorders and fatigue—linked to overexertion, slips, trips, and falls—have been reported

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among nurses, placing the profession among the high-risk jobs for nonfatal workplace injuries [5]. Previous studies have demonstrated that fatigue can increase postural sway after repetitive lifting among male and female workers [6].

In this regard, some researchers have examined the association between working at night and postural balance impairments to evaluate whether fatigue-related night work and sleepiness can affect the postural balance of shift workers [7-9]. For example, FV Narciso et al. (2016) reported that working continuously for 12 hours at night and the consequent drowsiness could negatively affect postural balance and psychomotor performance in shift workers [10].

According to estimates, nurses walk 4–5 miles [11]—approximately 9,000 steps—during a 12-hour shift [12]. Despite this, there remains a gap in understanding the association between shift work and gait biomechanics. It is crucial to examine the effect of night work on walking biomechanics, as most falls occur during walking, and gait evaluation can be considered an effective functional approach for predicting falls to ensure the safety of both nurses and patients [13].

Evidence suggests that working outside the typical 9:00 am–5:00 pm period, such as rotating shifts and night work, results in circadian rhythm misalignment, disrupting the synchrony between the body's internal clock and the external environment, leading to sleep disorders [1,14]. This disruption causes performance impairment, daytime sleepiness, health deterioration, physical and psychological distress, decreased alertness and vigilance [15,16], interruption of workers' recovery from fatigue [17], and poor dietary habits [18]. More specifically, there is a link between disrupted sleep and skeletal muscle health, which is essential for human movement, substrate storage, and plays a significant role in energy and protein metabolism in night workers [19].

Although no study has directly investigated skeletal muscle health in shift workers, Aisbett et al. suggested that artificial light exposure, sleep patterns, and eating habits could impact skeletal muscle function and health [19]. Considering that the nursing profession is physically demanding—ranking second only to industrial work [20]—it is assumed that the cumulative effects of fatigue, sleepiness, and impaired skeletal muscle function might influence nurses' physical activity.

To our knowledge, this is the first study to examine differences in biomechanical gait parameters between nurses working night versus day shifts. Therefore, the main purpose of this research was to assess the gait and dynamic stability of nurses. In the present study, we hypothesized that gait kinematics and dynamic stability would differ significantly between the two groups of night and day shift workers.

Methods

This cross-sectional study was approved by the Human Research Ethics Committee of Shiraz University of Medical Sciences (Ethics code: IR.SUMS.REC.1397.336). Convenience sampling was employed to select participants who met the inclusion criteria. All participants provided written informed consent after receiving a detailed explanation of the study procedures. Participants were female nurses working in the postsurgical orthopedic wards of Namazi and Chamran hospitals. The sample comprised 16 nurses working 12-hour night shifts from 8 p.m. to 8 a.m. (with at least 3 years of night shift experience) and 15 nurses working day shifts from 8 a.m. to 2 p.m.

Participants completed two questionnaires: the Morningness-Eveningness Stability Scale improved (MESSI) questionnaire and the Nordic Musculoskeletal Questionnaire to assess chronotype and ensure sample homogeneity [21, 22]. All participants were morning chronotypes with no history of musculoskeletal disorders. Exclusion criteria included regular physical exercise, pregnancy, sleep pattern disorders, visual or vestibular dysfunction, brain-related diseases, use of prostheses, neuromuscular diseases (e.g., Parkinson's disease, multiple sclerosis), sleeping for more than one hour during the shift, alcohol consumption during the day before measurements, and any special medical conditions.

Participants were evaluated immediately after their respective shifts. Testing occurred between 8–9 a.m. for night-shift nurses and 2–3 p.m. for day-shift nurses.

A Qualisys motion analysis system (Proreflex, Qualisys Track Manager® Ltd., Gothenburg, Sweden), consisting of eight high-speed cameras and Qualisys Track Manager software, was used to record walking kinematics and determine marker locations, respectively. Data were collected at a frequency of 120 Hz. Forty-three markers (19 mm in diameter) were placed bilaterally on anatomical landmarks, including the anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), iliac crests, acromion processes, medial and lateral sides of the knee joints, greater trochanters, first and fifth metatarsal heads, medial and lateral malleoli, second toe tip, and heels. Additionally, four cluster markers were attached to the anterolateral surfaces of the legs and thighs using extensible Velcro straps, and one marker was placed on the top of the head.

Participants walked along a flat pathway, and three acceptable walking trials at a comfortable self-selected speed were recorded for each participant. Only trials in which the participant's dominant foot landed on the force plate were used for further analysis. Data filtering was performed using a Butterworth low-pass filter with a cutoff frequency of 10 Hz. Gait cycle phases were determined using heel strike and toe-off data.

Data were imported into OpenSim software to build a musculoskeletal model with 23 degrees of freedom and 76 scaled muscles for each subject (Figure 1). To evaluate dynamic stability, force plate data were recorded using a Kistler force plate (Kistler Instrument®, Winterthur, Switzerland). Dynamic stability was assessed via center of mass (COM) movement in the mediolateral and vertical directions, which were normalized to the base of support and leg length of each subject, respectively.

The gait spatiotemporal parameters (stride length, cadence, and walking velocity), kinematics of the ankle, knee, and hip joints, as well as the pelvic and trunk segments during the stance phase of gait, and dynamic stability measurements were obtained from a subject-specific musculoskeletal model developed for each participant. The normality of the data distribution was assessed using the Shapiro-Wilk test. Group differences in all mentioned parameters were analyzed using independent-sample t-tests. All statistical analyses were performed using IBM® SPSS version 21.0 (IBM Corp., Armonk, NY, USA), with a significance level set at 0.05.

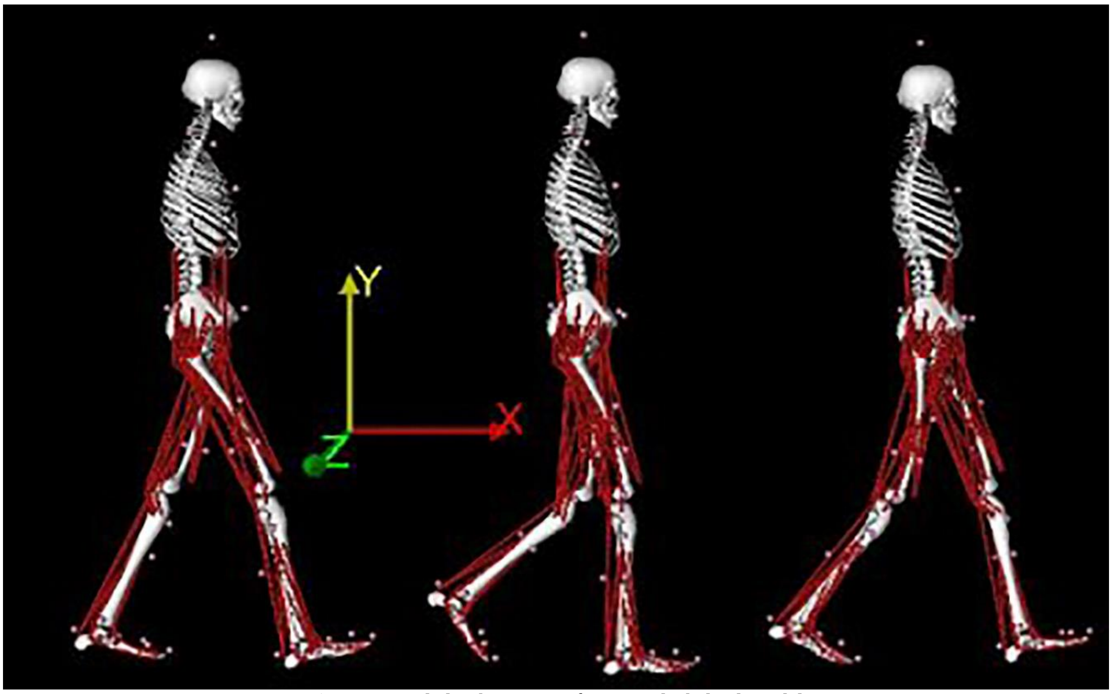

Figure 1: Scaled Subject-Specific Musculoskeletal Model.

Results

Demographic characteristics of the participants are summarized in Table 1. No significant differences were observed between the groups regarding demographic data. The mean walking speed of nurses working the day shift was 1.14 ± 0.13 m/s, compared to 1.16 ± 0.16 m/s for those working the night shift ($p = 0.33$) (Table 3). There were no significant differences in the mean values of spatiotemporal gait parameters between nurses working day and night shifts.

Regarding joint kinematics, although the range of pelvic and lumbar rotations increased after the night shift compared to the day shift, this difference was not statistically significant ($p > 0.05$). The mean values of the range of motion (ROM) for other joints in both day and night shift groups are presented in Table 2. Overall, no significant differences were found between the mean values of these parameters in day versus night shifts ($p > 0.05$).

Dynamic stability was also evaluated in this study and was assessed by tracking the movement of the center of mass (COM) in the vertical and mediolateral directions. The excursions of COM motion in the vertical and mediolateral directions were normalized to leg length and base of support, respectively. The results of dynamic stability are presented in Table 3. According to the data, the mean COM excursion in the vertical direction was $4.77 \pm 0.8\%$ of leg length for the day shift group and $4.36 \pm 0.89\%$ for the night shift group. COM movement in the mediolateral direction was significantly different between the two groups.

Table 1: Participants Characteristics

	Groups	N	Mean±SD	Range	P-value
	Day	15	66.80±6.94	54-76	0.11
Body mass (kg)	Night	16	63.19±10.32	43-80	
	Day	15	40.21±7.28	27-43	0.23
Age (y)	Night	16	33.25±5.59	27-47	
	Day	15	162.07±5.57	152-172	0.31
Height (cm)	Night	16	162.31±4.11	154-168	

Note: N: number of subjects in each group, SD: standard deviation; kg: kilogram; y: year; cm: centimeter.

Table 2: Comparison of Mean Joint Range of Motion (ROM) between Day and Night Shift Nurses

Parameters (Degree)	Day mean±SD	Night mean±SD	P-value
Pelvic Tilt	3.88±1.18	3.49±0.77	0.13
Pelvic List	9.82±2.66	9.6±1.81	0.39
Pelvic Rotation	9.99±4.34	11.13±3.4	0.21
Hip Flexion/Extension	45.5±3.6	47.5±4.43	0.09
Hip Abduction/Adduction	17.3±4.36	17.3±2.3	0.45
Hip Rotation	14.4±4.15	14.01±3.07	0.38
Knee Flexion/Extension	69.9±3.7	70.7±3.6	0.28
Ankle Plantar/Dorsi Flexion	27.3±2.4	27.12±3.16	0.43
Lumbar Flexion/Extension	5±1.17	4.6±0.92	0.12
Lumbar Abduction/Adduction	13.65±3.9	13.32±1.88	0.38
Lumbar Rotation	15±4.53	17.15±7.1	0.16

Note: SD: Standard deviation.

Table 3: Comparison of mean spatiotemporal gait parameters and center of mass (COM) movements between day and night shift nurses

Parameters	Day mean±SD	Night mean±SD	P-value
Velocity (m/sec)	1.14±0.13	1.16±0.16	0.33
Cadence (step/min)	112.8±9.1	117±13	0.15
Stride length (m)	1.21±0.07	1.19±0.094	0.27
COM movement in vertical (cm)	4.77±0.8	4.36±0.89	0.09
COM movement in mediolateral (cm)	3.1±19.7	4.46±16.93	0.02*

Note: SD: standard deviation; COM: center of mass.
* Significant difference in mean value, P < 0.05.

Discussion

It seems that those working night shifts may face greater challenges in regulating their activities, which not only affects their job performance but may also increase the incidence of physical and psychological health problems [23]. However, it is not yet well understood whether working at night influences gait characteristics. Moreover, it remains unclear whether night shift work impairs dynamic stability, potentially leading to an increased risk of falls. Therefore, this study aimed to compare the kinematic parameters and dynamic stability of nurses working day and night shifts.

It has been shown that fatigue resulting from working both day and night shifts may lead to impaired postural balance performance [5], which can reduce motor control and increase the range of motion, potentially affecting gait [24]. However, our findings do not align with these results, as we found no significant differences in the ranges of motion of the pelvic, hip, knee, and ankle joints between nurses working day and night shifts. Considering findings from previous studies reporting a strong relationship between range of motion (ROM) and walking speed [25], the results of the current study did not support this relationship, as we found no significant differences in gait velocity or ROM between the two groups. This might be due to the working conditions of night shift nurses, who may have sufficient time to rest [26]. Although we asked participants to avoid taking naps, we could not fully control this factor. Previous research has reported that napping can be considered a strategy to attenuate the adverse effects of night shift work and may contribute to improved working conditions, performance, and safety [27].

Although several studies have explored the effect of working at night on postural balance and stability among night workers [9,28], there is a paucity of knowledge about how night shifts affect the spatiotemporal gait parameters of nurses, which could, in turn, impact their performance and patient safety [29]. Previous studies have demonstrated that acute sleep deprivation may deteriorate postural stability and performance, leading to increased postural sway due to decreased vigilance, alertness, and an inability to maintain a stable position [10]. Because increased postural sway strongly affects walking patterns, we investigated whether there were differences in gait biomechanics between night and day shift workers. However, we found no significant differences in most of the spatiotemporal parameters, except for the center of mass (COM) movement in the mediolateral direction, which is more closely related to dynamic stability. Although we observed significant differences in mediolateral COM movement, no significant differences were found in gait kinematic variables between the two groups. This finding suggests that mediolateral fluctuations of COM do not affect joint range of motion or gait biomechanics, and thus no adaptive strategy is required [25]. Therefore, based on the results of our study, it can be concluded that there is no substantial difference in the gait patterns of night and day shift nurses, indicating no increased risk of falling while walking.

It has been noted that nursing roles vary depending on the unit in which they work—such as medical, surgical, operating theatre, mental health, pediatric, or emergency units—and these differing responsibilities may impose distinct physical activity demands. Consequently, the workload of nurses may differ based on the unit and associated duties. In the present study, we were unable to recruit nurses working in the same unit but on different shifts, which may have influenced the comparability of workload between the day and night shift groups [29].

One of the possible limitations of this study is that, although we collected data immediately after the nurses' shifts ended, it would have been more accurate to take measurements multiple times during their shifts. Previous research has suggested that the difficulty of tests, such as unipedal versus bipedal protocols, could influence the assessment of fatigue-related impairments in postural balance [30]. Therefore, future studies should be designed to examine postural balance variables under dual-task conditions. Additionally, we suggest that more conclusive results could be achieved by investigating the effects of prolonged sleep deprivation on muscle function at the molecular level, as well as its impact on locomotion, in future research.

Conclusion

This study is the first to investigate gait kinematic variations in nurses working both night and day shifts. Given that nursing is a physically demanding profession and that movement impairments in nurses can directly affect patient safety, it is essential to understand how sleeplessness and fatigue influence gait kinematics. Based on our findings, we concluded that there are no significant differences in spatiotemporal gait parameters, vertical indicators of dynamic stability, or joint range of motion between day and night shift nurses. These results suggest that working night shifts does not alter the biomechanical gait patterns of nurses.

Author's Contributions

MTK and MR reviewed the literature and conceived the study. MTK, FY, and MR were involved in protocol development, obtaining ethical approval, participant recruitment, and data analysis. FY and MR drafted the initial version of the manuscript. All authors reviewed and approved the final manuscript.

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Conflict of Interest: The authors declare no conflict of interest.

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