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ORIGINAL RESEARCH

Relationship between sleep quality, sleep duration, heart rate, and step counts in young adults

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Abstract

It was aimed to explore the connections among sleep quality, heart rate, sleep duration, quality of life, and step count in young adults. The study involved 116 young adults, comprising 61 women and 55 men. Sleep quality was evaluated using the Pittsburgh Sleep Quality Index (PSQI), and sleep duration, heart rate, step count, and energy expenditure were monitored with the Fitbit® Inspire 2. Quality of life was evaluated using the Nottingham Health Profile (NHP) Questionnaire. Correlation analysis was performed using either Pearson or Spearman correlation analysis. The study found no significant relationships between sleep quality, sleep duration, heart rate, and step count ($p< 0.05$). A very strong positive correlation was found between sleep score and both time asleep ($r = 0.730$) and REM sleep ($r = 0.743$), as well as a strong correlation with deep sleep ($r = 0.454$). Time asleep had very strong positive correlations with REM sleep ($r = 0.611$) and light sleep ($r = 0.782$), and strong correlations with awake time ($r = 0.438$) and deep sleep ($r = 0.466$). Awake time and light sleep also showed a strong correlation ($r = 0.585$). Additionally, step count was strongly correlated with energy expenditure ($r = 0.519$), and a very strong correlation was observed between the section 1 score of the NHP and the PSQI ($r = 0.649$). These outcomes underscore the complex interplay between sleep and physical activity and emphasize the importance of considering multiple factors when assessing health and quality of life.

Introduction

Sleep is a natural biological process involving alterations in consciousness, reduced sensory activity, and decreased voluntary muscle engagement, which minimizes interaction with the external environment. It is essential for maintaining normal physiological functions and overall health. Extensive research on sleep has revealed numerous adverse health outcomes linked to poor sleep quality. The immediate consequences of sleep disturbances include diminished task performance, accompanied by daytime fatigue and drowsiness (Mirjat et al., 2020). Several factors, such as lifestyle, work environment, socioeconomic status, social interactions, stress, and general health, can influence sleep quality (Mirjat et al., 2020; Nakie et al., 2024).

The adoption of mobile health technologies, particularly wearable sensors, has significantly expanded in sleep and physical activity research over recent years. The advantages of using commercially available wearable devices in research are evident—they are cost-effective, widely accessible, and consistently advancing in terms of accuracy, user convenience, and potential impact on healthcare outcomes (Jaiswal et al., 2024; Yoon & Choi, 2023). Headbands, wristwatches, rings, and patch-based devices are examples of wearable technologies that provide information on physical activity and sleep measurements (Yoon & Choi, 2023). Despite their increasing popularity, it remains unclear whether the use of wearable technologies directly affects sleep quality or quantity (De Zambotti et al., 2024).

Physical activity is closely linked to improved sleep quality, with increased activity levels often enhancing sleep duration and onset. Recognized by the American Sleep Disorders Association as a non-pharmacological approach, physical activity helps reduce sleep complications and promotes better rest. Studies show that higher fitness levels improve sleep quality, while low physical activity is associated with insomnia and sleep disorders, particularly in individuals with obesity. Even though most research highlights a positive

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relationship, some findings remain inconclusive, warranting further investigation (Alruwaili et al., 2023).

Although prior research has explored the connection between sleep quality and physical activity in young adults, these studies predominantly relied on self-reported measures such as the International Physical Activity Questionnaire (IPAQ), which may not comprehensively capture daily activity levels (İyigün et al., 2017; Moussa-Chamari et al., 2024; Özkan et al., 2015). This study seeks to address these gaps by using daily step counts, a more objective metric for physical activity, to investigate its association with sleep parameters such as sleep quality, heart rate, and sleep duration. Furthermore, this research aims to evaluate how these factors collectively influence the overall quality of life in young adults. We hypothesize that increased physical activity, as measured by daily step counts, will positively correlate with better sleep quality, longer sleep duration, and a more stable heart rate. Additionally, these improvements in sleep parameters are expected to contribute to a higher overall quality of life.

Methods

Participants

The study was designed as a cross-sectional, descriptive face-to-face evaluation. The study was conducted at Tokat Gaziosmanpaşa University Faculty of Health Sciences. The study included healthy, sedentary young adults aged 18–30 who did not engage in regular exercise or sports activities. Individuals were excluded if they had any health condition, either temporary or permanent, that could hinder participation in physical activity (e.g., musculoskeletal disorders, neurological diseases, or the presence of pain). Additionally, participants were excluded if they were using any medication that could potentially influence the study variables (e.g., opioids or antidepressants), had sleep irregularities, were diagnosed with any sleep-related condition, or were undergoing treatment or using medication for such conditions. A power analysis using the G*Power program determined the sample size. Based on the reference study, with a significance level (α) of 0.05, an effect size (d) of 0.3, and a power (β) of 0.95, the required sample size was calculated to be 111 participants and 116 participants included this study.

Informed consent was obtained from all participants who volunteered for the study. The study received ethical approval from the Clinical Research Ethics Committee of Tokat Gaziosmanpaşa University Faculty of Medicine (decision no: 83116987-614, dated October 6, 2022). It was also registered on ClinicalTrials.gov (NCT05829525).

Outcome Measures

Sleep quality

The Pittsburgh Sleep Quality Index (PSQI) is a scale designed to assess sleep quality and the type and severity of sleep disturbances over the past week. Comprising a total of 24 questions, the scale requires the individual to answer 19, while their bed partner answers the remaining 5. The PSQI evaluates 7 sub-dimensions: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction. Each item is scored from 0 (no distress) to 3 (severe distress). The total PSQI score, which ranges from 0 to 21, is calculated by summing the scores from the seven sub-dimensions. A total score of 5 or greater indicates "poor sleep quality;" while a score less than 5 indicate "good sleep quality." The PSQI, created by Buysse et al. (Buysse et al., 1989), was validated and tested for reliability in Turkish by Ağargün et al. (1996).

Sleep time, heart rate, step count, and energy expenditure

Sleep duration, step count, average heart rate, and energy expenditure were assessed using the Fitbit® Inspire 2 (Fitbit, Inc., San Francisco, California, USA), which participants wore on one wrist for a full day without removal to ensure accurate data recording. They were instructed to maintain their usual activities, and measurements were repeated if irregularities occurred. Data was delivered to smartphones or tablets via Bluetooth through the Fitbit App and website. To protect privacy, the Fitbit app was only installed on the principal researcher's device, and separate accounts were created for each Fitbit device, ensuring that no personal information was shared. The proprietary software algorithm used by Fitbit for analyzing accelerometer and heart rate variability (HRV) data was developed based on sleep laboratory studies and machine learning for users without sleep disorders (Beattie et al., 2017). Participants were advised to position the Fitbit® Inspire 2 approximately one finger above wrist level as per the manufacturer's guidelines.(Haghayegh et al., 2020) The reliability and accuracy of the Fitbit® Inspire 2's accelerometer, heart rate, and sleep assessment features have been documented in studies (Haghayegh et al., 2019; Rowe & Neville, 2019; Van Camp, 2020). Regarding sleep, time

asleep (REM sleep + light sleep + deep sleep), awake, REM sleep, light sleep, and deep sleep parameters were recorded.

Sleep quality was primarily assessed using data from the Fitbit Inspire 2 device, as it provides more objective measurements of sleep duration and quality. These data represent the average values calculated over three consecutive days, not just one day. The Pittsburgh Sleep Quality Index (PSQI) was used to complement and support the Fitbit data by providing a subjective evaluation of sleep quality over the past week. Similarly, step counts, heart rate, and energy expenditure were also recorded over three days, and their average was used for analysis.

Quality of life

The Nottingham Health Profile (NHP) Questionnaire was used to measure quality of life. As a general quality-of-life instrument, the NHP evaluates perceived health concerns and their impact on daily living. Originally developed by Hunt et al. (1981), the questionnaire was adapted into Turkish and validated by Küçükdeveci et al. (1997). The questionnaire comprises 38 items answered with 'yes' or 'no.' It evaluates six health-related parameters: pain (8 items), physical activity (8 items), energy (3 items), sleep (5 items), social isolation (5 items), and emotional reactions (9 items). Each parameter is scored from 0 to 100, where 0 represents optimal health and 100 represents the poorest health. The total NHP score is calculated as the sum of these sub-scores (Kücükdeveci et al., 2000).

Data Analyses

SPSS version 22.0 (SPSS Inc., Chicago, IL) was used to carry out all statistical analyses. Means and standard deviations were used to present continuous data (age, weight, height, BMI, sleep scores, number of steps, heart rate, energy expenditure, NHP scores and PSQI score), whereas counts and percentages were used for categorical data (gender, smoking, alcohol use). The normality of continuous data was tested using the Kolmogorov-Smirnov test. If the numerical variables showed normal distribution, the relationship among them was examined with the Pearson correlation test, and if they did not show normal distribution, the relationship among them was examined with Spearman correlation analysis. The correlation coefficient is categorized within the ranges of 0.81 to 1.00, 0.61 to 0.80, 0.41 to 0.60, 0.21 to 0.40, and 0.00 to 0.20, corresponding to excellent, very strong, strong, weak, and negligible correlations, respectively (Feise & Menke, 2001). In all statistical analyses, a significance level of $p<0.05$ was used.

Results

A total of 116 young adults, consisting of 61 women and 55 men, were included in the study. The demographic information of the participants is presented in Table 1. Descriptive data on variables such as sleep score, sleep duration, sleep stages, step count, heart rate, energy expenditure, quality of life, and sleep quality are shared in Table 2.

Table 1

Demographic profiles of individuals (n= 116).

Variables	Mean ± SD
Age (years)	22.90 ± 2.63
Weight (kg)	66.20 ± 12.24
Height (m)	1.70 ± 0.09
BMI (kg/m^2)	22.69 ± 3.01
	n (%)
Gender	
Female	61 (52.6 %)
Male	55 (47.4 %)
Smoking	
Yes	32 (27.6 %)
No	84 (72.4 %)
Alcohol Use	
Yes	9 (7.8 %)
No	107 (92.2 %)

SD: Standart deviation; kg: Kilogram; m: Meter; kg/m^2: Kilogram/meter^2

The results of the correlations between sleep score, sleep duration, sleep stages, step count, heart rate, energy expenditure, quality of life, and sleep quality are presented in Table 3. While significant correlations were observed among different parameters, the notable ones are as follows: A very strong positive correlation was found between sleep score with time asleep (r = 0.730) and REM (r = 0.743); a strong positive correlation was found between sleep score and deep sleep (r = 0.454). Time asleep showed a strong positive correlation with awake (r = 0.438) and deep sleep (r = 0.466), and a very strong positive correlation with REM (r = 0.611) and light sleep (r = 0.782). Awake and light sleep showed a strong positive correlation (r = 0.585). There was also a strong positive correlation between step count and energy expenditure (r = 0.519). A very strong positive correlation was recorded between section 1 score of the NHP and PSQI (r = 0.649).

Table 2
Descriptive values of individuals regarding sleep quality, sleep duration, heart rate, step counts, and quality of life (n= 116).

	Mean ± SD	Minimum	Maximum
Sleep score	76.00 ± 5.32	59.00	88.33
Time asleep (minutes)	376.15 ± 55.27	246.00	548.67
Awake (minutes)	54.74 ± 14.32	30.00	131.67
REM sleep (minutes)	80.65 ± 25.09	26.00	154.00
Light sleep (minutes)	223.50 ± 41.51	126.67	350.00
Deep sleep (minutes)	72.00 ± 16.02	31.00	115.67
Number of steps	9916.71 ± 3977.26	2531.00	23399.00
Heart rate (bpm)	68.95 ± 5.48	55.00	85.67
Energy expenditure (calories)	2345.65 ± 475.12	1153.00	3579.67
Pain (NHP)	5.83 ± 10.22	0.00	51.53
Emotional reactions (NHP)	25.56 ± 25.81	0.00	100.00
Sleep (NHP)	28.52 ± 29.06	0.00	100.00
Social isolation (NHP)	17.40 ± 25.18	0.00	100.00
Physical mobility (NHP)	4.62 ± 8.03	0.00	33.53
Energy (NHP)	32.72 ± 38.69	0.00	350.34
Section 1 total score (NHP)	114.64 ± 91.27	0.00	350.34
Section 2 (NHP)	0.21 ± 0.65	0.00	5.00
PSQI score	6.41 ± 2.79	1.00	14.00

SD: Standard deviation; bpm: Beats per minute; Light sleep: NREM stage 1+2; Deep sleep: NREM stage 3; NHP: Nottingham Health Profile Questionnaire; PSQI: Pittsburgh Sleep Quality Index.

Discussion

This study was designed to investigate whether there is a relationship between sleep quality, sleep duration, heart rate, and number of steps, energy expenditure, and quality of life. The main finding of the study was that no significant relationship was found between sleep quality, sleep duration, heart rate, and step count. Additionally, a strong relationship was observed between step counts and energy expenditure, as well as between sleep quality and quality of life.

Sleep plays a critical role in the optimal functioning of organ systems, including the musculoskeletal system. A typical night's sleep lasts between 7-9 hours, with durations shorter than 7 hours often considered insufficient (Anderson et al., 2022). Sleep duration encompasses the total time spent sleeping and is closely tied to the progression through various sleep stages, including light sleep (NREM stages 1 and 2), deep sleep (NREM stage 3), and rapid eye movement (REM) sleep. Adequate sleep duration ensures a proper balance across these stages, supporting both physical recovery during deep sleep and cognitive functions like memory consolidation during REM sleep. Consequently, sleep duration strongly influences overall sleep quality. In this study, the insufficient sleep duration observed in participants may partly explain the lack of strong correlations between sleep-related parameters such as sleep quality, sleep duration, and heart rate. This highlights the need to explore additional factors or confounders, such as stress or lifestyle habits, that may mediate these relationships in young adults. Supporting this notion, a previous study found that sleep quality is significantly associated with various physical and mental health parameters, including body perception, self-esteem, depression, anxiety, stress, physical activity levels, and quality of life subdimensions like "physical function," "body pain," "general health," "mental health," and "vitality" (İyigün et al., 2017). Consistent with these findings, the current study demonstrates a strong relationship between sleep quality and overall quality of life in young adults. However, the absence of a direct association between step count and sleep quality in our findings suggests that individual and lifestyle factors, such as stress, may overshadow the potential impact of physical activity on sleep.

Table 3
The relationship among individuals' sleep quality, sleep duration, heart rate, step counts, and quality of life values (n= 116).

Variables		Time Asleep	Awake	REM Sleep	Light Sleep	Deep Sleep	Number of Steps	Heart Rate	Energy Expenditure	Section 1 of NHP	Section 2 of NHP	PSQI
Sleep Score	r	**0.730** $^{\alpha}$	0.010 $^{\beta}$	**0.743** $^{\alpha}$	**0.348** $^{\alpha}$	**0.454** $^{\alpha}$	-0.074 $^{\beta}$	**0.236** $^{\alpha}$	0.056 $^{\alpha}$	0.029 $^{\beta}$	0.033 $^{\beta}$	0.039 $^{\beta}$
	p	**0.000**	0.914	**0.000**	**0.000**	**0.000**	0.431	**0.011**	0.548	0.757	0.721	0.680
Time Asleep	r		**0.438** $^{\beta}$	**0.611** $^{\alpha}$	**0.782** $^{\alpha}$	**0.466** $^{\alpha}$	**-0.215** $^{\beta}$	**0.255** $^{\alpha}$	-0.116 $^{\alpha}$	-0.052 $^{\beta}$	-0.007 $^{\beta}$	-0.059 $^{\beta}$
	p		**0.000**	**0.000**	**0.000**	**0.000**	**0.021**	**0.006**	0.215	0.577	0.941	0.527
Awake	r			0.015 $^{\beta}$	**0.585** $^{\beta}$	0.040 $^{\beta}$	**-0.243** $^{\beta}$	0.086 $^{\beta}$	**-0.220** $^{\beta}$	-0.021 $^{\beta}$	-0.028 $^{\beta}$	-0.063 $^{\beta}$
	p			0.869	**0.000**	0.670	**0.009**	0.360	**0.018**	0.827	0.762	0.504
REM Sleep	r				0.063 $^{\alpha}$	**0.375** $^{\alpha}$	**-0.190** $^{\beta}$	0.183 $^{\alpha}$	-0.013 $^{\alpha}$	0.077 $^{\beta}$	0.031 $^{\beta}$	0.058 $^{\beta}$
	p				0.493	**0.000**	**0.041**	0.050	0.890	0.411	0.743	0.536
Light Sleep	r					0.008 $^{\alpha}$	-0.172 $^{\beta}$	0.097 $^{\alpha}$	-0.113 $^{\alpha}$	-0.128 $^{\beta}$	-0.102 $^{\beta}$	-0.114 $^{\beta}$
	p					0.935	0.064	0.300	0.228	0.171	0.277	0.223
Deep Sleep	r						-0.086 $^{\beta}$	**0.343** $^{\alpha}$	-0.088 $^{\alpha}$	0.120 $^{\beta}$	0.043 $^{\beta}$	0.098 $^{\beta}$
	p						0.359	**0.000**	0.350	0.199	0.643	0.297
Number of Steps	r							-0.180 $^{\beta}$	**0.519** $^{\beta}$	-0.060 $^{\beta}$	0.097 $^{\beta}$	-0.016 $^{\beta}$
	p							0.054	**0.000**	0.524	0.302	0.863
Heart Rate	r								**-0.283** $^{\alpha}$	0.004 $^{\beta}$	0.003 $^{\beta}$	-0.053 $^{\beta}$
	p								**0.002**	0.963	0.977	0.575
Energy Expenditure	r									0.043 $^{\beta}$	0.040 $^{\beta}$	0.146 $^{\beta}$
	p									0.643	0.667	0.117
Section 1 of NHP	r										**0.374** $^{\beta}$	**0.649** $^{\beta}$
	p										**0.000**	**0.000**
Section 2 of NHP	r											**0.231** $^{\beta}$
	p											**0.013**

$^{\alpha}$: Pearson correlation analysis; $^{\beta}$: Spearman correlation analysis; Light sleep: NREM stage 1+2; Deep sleep: NREM stage 3; NHP: Nottingham Health Profile Questionnaire; PSQI: Pittsburgh Sleep Quality Index.

Physical activity encompasses any bodily movement generated by skeletal muscles that leads to energy expenditure (Caspersen et al., 1985). While physical activity inherently increases energy expenditure beyond resting levels, total energy expenditure reflects the cumulative energy used within a 24-hour period (Pinheiro Volp et al., 2011; (Ndahimana & Kim, 2017). Although these two variables are interdependent, investigating their correlation helps validate research tools and confirm anticipated patterns. In this study, the strong correlation observed between physical activity and energy expenditure aligns with previous findings, emphasizing the direct relationship between activity intensity, duration, and energy consumption. Complementing this, a study examining physical activity, insomnia, and psychological well-being in university students demonstrated that higher physical activity levels enhanced psychological well-being and reduced insomnia (Demirer & Erol, 2020). The current study found that physical activity, represented by step count, strongly correlated with energy expenditure but did not directly affect subjective sleep quality measures. This suggests that sleep quality is a multidimensional construct influenced by factors such as stress, lifestyle, and individual differences, which may outweigh the direct impact of physical activity levels. These findings highlight the intricate relationship between physical activity, sleep, and overall well-being, underscoring the need for future studies to incorporate measures of stress, mental health, and lifestyle to better understand these dynamics.

Sleep plays a crucial role in determining physical health, mental well-being, and overall quality of life. For many young adults, achieving sufficient sleep is often hindered by lifestyle, social, academic, or professional demands (Panel et al., 2015). This study observed a strong relationship between sleep quality and quality of life, underscoring the profound impact of sleep on daily functioning and overall well-being. Poor sleep quality, as reflected in the study population, is linked to reduced physical, emotional, and cognitive capacities, ultimately diminishing quality of life. These findings align with previous research, which associates inadequate sleep with heightened risks of chronic diseases, weakened immune function, and impaired mental health (Lee et al., 2021). The interrelations among sleep quality, mental health, and physical activity across different domains of quality of life (QOL) in university students have been elucidated. The results revealed that environmental QOL is associated with both sleep quality and physical activity. The relationship between sleep quality and both physical and mental QOL suggests a potential impact on subsequent health-related outcomes. Depression, stress, and anxiety strongly influence psychological health QOL (Moussa-Chamari et al., 2024). The results highlight the importance of prioritizing sleep quality in interventions aimed at enhancing quality of life, particularly for young adults vulnerable to sleep deprivation due to demanding routines. Additionally, while this study confirmed the contribution of physical activity, represented by step count, to overall health, it found no direct association between physical activity and subjective sleep quality. This suggests that sleep quality is shaped by a broader set of factors, including stress, lifestyle habits, and individual variability, which may overshadow the direct influence of physical activity. Future research should explore these multidimensional contributors to provide a more comprehensive understanding of the mechanisms driving sleep quality.

Although sleep quality, sleep duration, heart rate, and step count are commonly studied metrics in health and wellness research (Anderson et al., 2022; Chevance et al., 2022; Sayaca & Karaman, 2021), these variables may not be related to each other. Sleep quality and duration reflect the restorative aspects of sleep, influenced by factors such as stress, environment, and individual health conditions. In contrast, heart rate and step count primarily indicate physical activity levels and cardiovascular health. Given the distinct physiological processes and external influences affecting each metric, the expectation of a correlation between them may be unrealistic. For example, an individual with high step counts and a low resting heart rate due to regular exercise may still experience poor sleep quality or insufficient duration because of stress or lifestyle factors. Thus, the lack of significant correlations among these metrics does not diminish their individual importance. Instead, it highlights the complexity of human health and the multifaceted interactions shaping these variables, emphasizing the need for a holistic approach to understanding health outcomes.

Conclusion

This study investigated the relationships between various sleep parameters, physical activity, heart rate and quality of life among young adults. Higher sleep scores were closely associated with longer sleep duration and increased REM sleep, reflecting the critical role of sleep stages in overall sleep quality. Additionally, physical activity, as measured by step count, was positively related to energy expenditure, underscoring

the impact of activity levels on metabolic outcomes. The study also highlighted a strong link between quality of life and sleep quality, suggesting that improvements in sleep may enhance overall well-being. These results underscore the complex interplay between sleep and physical activity and emphasize the importance of considering multiple factors when assessing health and quality of life.

Several limitations exist in this study that must be acknowledged when analyzing the results. The study relied on the Fitbit Inspire 2 device to measure sleep duration, heart rate, and step count. While wearable technology like the Fitbit provides convenient and continuous monitoring, it may not be as accurate as clinical-grade devices. Because of the cross-sectional nature of the study, establishing causality between the measured variables is not possible. Since data were collected at a single point in time, it is not possible to establish the directionality or causation of the observed relationships. Lastly, external factors such as stress levels, diet, physical environment, and lifestyle habits were not controlled for, which could influence the variables under study, particularly sleep quality and quality of life. Future research needs to overcome these limitations by utilizing larger and more varied samples, implementing longitudinal designs for assessing causality, and adopting more accurate measurement tools to bolster the validity and reliability of the results.

Authors' Contribution

Study Design: HA, AK; Data Collection: HA, AK; Statistical Analysis: HA; Manuscript Preparation: HA, AK.

Ethical Approval

The study was approved by the Tokat Gaziosmanpaşa University of Non-invasive Clinical Research Ethical Committee (2022/83116987-614) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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