

Physical Activity, Health-Related Physical Fitness, Sleep Quality, and Psychological Status Among Saudi Female University Students: A Cross-Sectional Study

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Abstract

Background

University students are particularly vulnerable to unhealthy lifestyle behaviors, including physical inactivity, prolonged sedentary behavior, poor sleep, and psychological distress. These lifestyle factors may negatively influence both physical and mental health, particularly among young women. This study examined the relationships between physical activity, sedentary behavior, body composition, cardiorespiratory fitness, sleep quality, and psychological well-being among Saudi female university students.

Methods

A cross-sectional study was conducted among 73 female university students (age: 19.6 ± 1.5 years). Body mass index (BMI), body fat percentage (BF%), estimated cardiorespiratory fitness ($VO_2\text{max}$), grip strength, and flexibility were objectively measured. Physical activity and sedentary behavior were assessed using the International Physical Activity Questionnaire-Short Form (IPAQ-SF). Sleep quality was evaluated using the Pittsburgh Sleep Quality Index (PSQI), and psychological status was assessed using the Depression Anxiety Stress Scales (DASS-21). Descriptive statistics, Spearman correlations, Mann-Whitney U tests, chi-square tests, and multiple linear regression analyses were performed.

Results

Body fat percentage was positively correlated with BMI ($r = 0.686$, $p < 0.001$) and sitting time ($r = 0.237$, $p = 0.043$) and negatively correlated with estimated $VO_2\text{max}$ ($r = -0.248$, $p = 0.035$). Sleep quality was positively associated with stress ($r = 0.532$, $p < 0.001$), anxiety ($r = 0.507$, $p < 0.001$), and depression ($r = 0.332$, $p = 0.004$). Multiple linear regression revealed that the overall model significantly predicted sleep quality ($R^2 = 0.473$, adjusted $R^2 = 0.388$, $p < 0.001$). Stress was the only significant independent predictor of poorer sleep quality ($\beta = 0.469$, $p = 0.002$).

Conclusions

Among Saudi female university students, sleep quality was more strongly associated with psychological stress than with physical activity or cardiorespiratory fitness. Lower fitness was associated with less favorable body composition. These findings highlight the importance of integrated lifestyle and mental health interventions targeting sleep hygiene, stress management, and physical health in young women.

Background

University life represents an important transitional period during which young adults experience substantial academic, social, and lifestyle changes that may influence both physical and mental health [1–3]. The transition into higher education is often accompanied by increased academic demands, prolonged sedentary time, irregular sleep patterns, reduced physical activity, and elevated psychological stress [4–7]. Because health behaviors established during young adulthood may persist later in life, the university years represent an important period for identifying potentially modifiable factors associated with health and well-being [8].

Lifestyle behaviors, including physical activity, sedentary behavior, and sleep, are important components of women's physical and psychological health. Regular physical activity is associated with favorable cardiovascular health and body composition [8, 9], better psychological well-being [10], and improved sleep outcomes [11]. Conversely, insufficient physical activity and prolonged sedentary behavior have been associated with adverse cardiometabolic outcomes and poorer overall health [12, 13]. These relationships may be particularly relevant during young adulthood, when academic demands and increasingly sedentary routines can compete with opportunities for regular physical activity and other health-promoting behaviors.

Physical fitness provides complementary information about health that is not necessarily captured by self-reported physical activity alone. In particular, cardiorespiratory fitness (CRF), commonly expressed as maximal or estimated oxygen uptake (VO_2max), reflects the integrated capacity of the cardiovascular, respiratory, and musculoskeletal systems and is recognized as an important indicator of cardiovascular and metabolic health [14, 15]. Higher CRF is associated with more favorable cardiometabolic health and lower risks of cardiovascular disease and premature mortality [14, 16]. Whereas physical activity questionnaires characterize recalled behavior, CRF reflects physiological capacity and may therefore provide complementary information when evaluating lifestyle and health [15, 17]. Other components of health-related fitness, including body composition, muscular strength, and flexibility, may further contribute to a broader characterization of physical health. Integrating these physiological measures with lifestyle behaviors may therefore provide a more comprehensive assessment of health in young women.

Sleep represents an additional component linking lifestyle with psychological well-being. Poor sleep is common among university students and has been associated with impaired cognitive functioning, poorer academic performance, emotional difficulties, and diminished well-being [18, 19]. Importantly, sleep and psychological health are closely interconnected, with sleep disturbances consistently associated with stress, anxiety, and depressive symptoms [20]. Women may be particularly relevant to this relationship because sex and gender differences have been reported in both sleep health and the prevalence of anxiety and depressive symptoms [21, 22]. Examining sleep alongside psychological status and modifiable lifestyle characteristics may therefore provide important insight into the broader factors associated with mental well-being in young women.

Despite growing interest in lifestyle and mental health among university students, physical activity, sedentary behavior, sleep, psychological health, and physical fitness are frequently examined as separate or partially overlapping domains. Comparatively less is known about how self-reported lifestyle behaviors relate concurrently to objectively assessed health-related fitness, body composition, sleep quality, and psychological status within the same population of young women. This distinction is important because behavioral measures of physical activity may not necessarily correspond directly with physiological fitness, while sleep and psychological distress may exhibit particularly close relationships. Evidence integrating these dimensions among Saudi female university students remains limited. Therefore, the present study aimed to examine the relationships among physical activity, sedentary behavior, health-related physical fitness, body composition, sleep quality, and psychological status among Saudi female university students. Specifically, we examined whether physical activity and sedentary behavior were associated with physical fitness and body composition and whether sleep quality was associated with stress, anxiety, and depressive symptoms. We further examined the independent contributions of physiological, behavioral, and psychological factors to sleep quality.

Methods

Study design

This cross-sectional study was conducted among female university students at a public university in Riyadh, Saudi Arabia, between March and May 2026. The study examined the relationships among physical activity, sedentary behavior, health-related physical fitness, body composition, sleep quality, and psychological status. All physical assessments were conducted in dedicated sport science testing facilities within the university using standardized procedures. The study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations for cross-sectional studies.

Participants

A convenience sample of 73 female university students was recruited through university-based advertisements and voluntary invitations. Interested students were provided with information about the study and screened for eligibility before enrollment. Participants were eligible if they were currently enrolled female university students, were able to safely complete the physical assessments, and provided informed consent to participate. Students were excluded if they reported chronic medical conditions or musculoskeletal injuries that could interfere with their ability to perform the physical assessments or if they did not complete the required measurements and questionnaires. These criteria were consistent with those established in the original study protocol.

Sample size

A priori power analysis was conducted using G*Power 3 [23] for the primary correlational analyses. Assuming a moderate bivariate correlation ($r = 0.30$), a two-sided α of 0.05, and statistical power of 80%, the minimum required sample size was 67 participants. The final sample of 73 participants therefore exceeded the minimum required for the primary correlational analyses. The multivariable regression analyses were conducted as secondary exploratory analyses and were not the basis of the original sample-size calculation.

Ethical considerations

The study protocol was approved by the relevant Institutional Review Board (IRB No. 26–0529). Before participating, all students received information regarding the study objectives and procedures and provided written informed consent. Participation was voluntary, and all procedures were conducted in accordance with the principles of the Declaration of Helsinki.

Data collection

All assessments were conducted using standardized procedures. Participants were instructed to avoid strenuous physical activity for at least 12 h before testing, refrain from eating for 4 h and consuming caffeinated beverages for 6 h before assessment, consume approximately 500 mL of water 2 h before the visit to maintain adequate hydration, and obtain adequate sleep the night before testing whenever possible. Upon arrival, participants completed questionnaires assessing physical activity and sedentary behavior, sleep quality, and psychological status. Physical assessments were then conducted in the following standardized order: anthropometry and body composition, cardiorespiratory fitness, handgrip strength, and flexibility.

Anthropometry and body composition

Height was measured using a fixed stadiometer while participants stood barefoot in an upright position, with the head facing forward, and was recorded to the nearest 0.1 cm. Body mass was measured using a calibrated electronic scale while participants wore light sports clothing and no shoes and was recorded to the nearest 0.1 kg. BMI was calculated as body mass (kg) divided by height squared (m^2) and classified according to World Health Organization criteria as underweight ($< 18.5 \text{ kg/m}^2$), normal weight ($18.5\text{--}24.9 \text{ kg/m}^2$), overweight ($25.0\text{--}29.9 \text{ kg/m}^2$), or obesity ($\geq 30.0 \text{ kg/m}^2$) (World Health Organization, 1998).

Body fat percentage (BF%) was estimated using an Omron bioelectrical impedance analysis (BIA) device (HBF-306). BIA estimates body composition from the resistance of body tissues to a low-level electrical current. BIA provides a non-invasive method for estimating body composition based on the electrical properties and hydration of body tissues [25, 26]. Because BIA estimates may be influenced by hydration status, recent food and fluid intake, and physical activity, standardized measurement conditions are

recommended to improve the consistency of measurements [27]. To reduce measurement variability, participants were instructed to avoid strenuous exercise and substantial food intake before assessment and to empty their bladder before measurement. Shoes, socks, and metallic accessories were removed, and measurements were performed under relatively similar environmental conditions whenever possible [27].

Cardiorespiratory fitness assessment

Cardiorespiratory fitness was estimated using the Queens College Step Test according to the protocol described by Heyward and Gibson (2014), based on the original protocol developed by McArdle et al. (1972). Participants stepped on and off a 41.3-cm bench for 3 min at a cadence of 22 steps·min⁻¹, controlled using a metronome. Immediately after completing the test, participants remained standing. Following a 5-s recovery period, heart rate was assessed for 15 s and multiplied by four to obtain beats per minute. Estimated VO₂max was subsequently calculated using the sex-specific prediction equation for women: $\text{VO}_2\text{max (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 65.81 - (0.1847 \times \text{recovery heart rate [beats}\cdot\text{min}^{-1}])$ (Gibson et al., 2024; McArdle et al., 1972). Because VO₂max was estimated from a submaximal field test rather than directly measured using respiratory gas analysis, the terms estimated VO₂max and estimated CRF are used throughout the manuscript.

Handgrip strength

Handgrip strength was assessed using a handgrip dynamometer as an indicator of isometric muscular strength. Handgrip dynamometry has demonstrated good validity and excellent reliability for the assessment of grip strength, including in healthy populations [30, 31]. During testing, participants held the dynamometer in alignment with the forearm at approximately thigh level while keeping the arm away from the body. They were instructed to squeeze with maximal effort while maintaining normal breathing and avoiding breath holding or a Valsalva maneuver. Neither the hand nor the dynamometer was allowed to contact the body or another external object. Two trials were performed with each hand, with a brief recovery period between attempts. The highest value obtained for each hand was recorded in kilograms, and the best values from the right and left hands were summed to derive the total handgrip-strength score.

Flexibility

Flexibility was assessed using the sit-and-reach test, a commonly used field-based assessment of flexibility that primarily reflects hamstring extensibility [28]. Participants removed their shoes and sat with their knees fully extended and the soles of their feet positioned against the sit-and-reach box. They were instructed to reach forward slowly with both hands parallel while maintaining full knee extension and avoiding bouncing movements. The maximal reach position was held for approximately 2 s. Two

trials were performed with a brief recovery period between attempts, and the greatest distance reached was recorded in centimeters and retained for analysis.

Physical activity and sedentary behavior

Physical activity and sedentary behavior were assessed using the Arabic version of the International Physical Activity Questionnaire–Short Form (IPAQ-SF). The IPAQ-SF assesses the frequency and duration of walking, moderate-intensity physical activity, vigorous-intensity physical activity, and sitting during the last 7 days [32].

Total physical activity was expressed as metabolic equivalent minutes per week (MET-min/week). According to the IPAQ scoring protocol, MET values of 3.3, 4.0, and 8.0 were assigned to walking, moderate-intensity activity, and vigorous-intensity activity, respectively. MET-min/week for each intensity was calculated by multiplying the corresponding MET value by the reported duration (min/day) and frequency (days/week), and these values were summed to derive total physical activity. Participants were classified as having low, moderate, or high physical activity according to established IPAQ scoring criteria.

Because only two participants were classified in the low-activity category, this group was excluded from analyses comparing physical activity categories; therefore, categorical comparisons were restricted to the moderate- and high-activity groups. Total physical activity (MET-min/week) was retained as a continuous variable for correlation and regression analyses.

Sedentary behavior was assessed using self-reported daily sitting time from the IPAQ-SF and analyzed as a continuous variable. For categorical analyses, sitting time ≥ 8 h/day was used to characterize high sedentary time, based on epidemiological evidence demonstrating increased health risks associated with prolonged daily sitting [33].

Sleep quality

Sleep quality was assessed using the Arabic version of the Pittsburgh Sleep Quality Index (PSQI). PSQI is a self-reported instrument that assesses sleep quality and disturbances over the preceding month across seven components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. Component scores are summed to generate a global score ranging from 0 to 21, with higher scores indicating poorer sleep quality [34]. The Arabic version of the PSQI has undergone translation and psychometric evaluation [35].

In the present sample, internal consistency across the seven PSQI components was Cronbach's $\alpha = 0.61$. The global PSQI score was analyzed as a continuous variable in correlation and regression analyses. For categorical analyses, participants were classified as having good sleep quality (PSQI ≤ 5) or poor sleep quality (PSQI > 5), consistent with the cutoff established in the original validation study [34].

Psychological status

Psychological status was assessed using the Arabic version of the 21-item Depression Anxiety Stress Scales (DASS-21) [36]. DASS-21 comprises three seven-item subscales assessing symptoms of depression, anxiety, and stress. Items are rated on a four-point scale ranging from 0 ("did not apply to me at all") to 3 ("applied to me very much or most of the time"), with higher scores indicating greater symptom severity. Subscale scores were calculated according to the instrument's scoring procedures. The Arabic DASS-21 has previously demonstrated good psychometric properties [37]. Internal consistency was excellent in the present sample, with Cronbach's α values of 0.91 for stress, 0.92 for anxiety, and 0.94 for depression.

Data analysis

Statistical analyses were performed using IBM SPSS Statistics, version 27 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized using means and standard deviations or medians and interquartile ranges, as appropriate, whereas categorical variables were summarized using frequencies and percentages. Because several study variables did not meet assumptions of normality, Spearman's rank-order correlation coefficients (ρ) were used to examine bivariate associations among anthropometric measures, BF%, estimated VO_2max , handgrip strength, flexibility, total physical activity, sitting time, global PSQI score, depression, anxiety, and stress.

The Mann-Whitney U test was used to compare continuous outcomes between two independent groups when distributional assumptions for parametric testing were not satisfied. Associations between categorical variables, including physical activity category and sleep-quality classification, were examined using the Pearson chi-square test, with Fisher's exact test used when expected cell frequencies were small.

Multiple linear regression was performed as a secondary exploratory analysis to examine the independent associations of physiological, behavioral, and psychological variables with sleep quality. Global PSQI score was entered as the dependent variable, while BMI, BF%, estimated VO_2max , handgrip strength, flexibility, total physical activity, sitting time, depression, anxiety, and stress were entered simultaneously as independent variables.

Overall model fit was evaluated using the F statistic, coefficient of determination (R^2), and adjusted R^2 . Individual predictors were evaluated using unstandardized regression coefficients (B), standard errors, standardized coefficients (β), 95% confidence intervals, and p values. Regression assumptions, including linearity, independence of residuals, homoscedasticity, normality of residuals, and multicollinearity, were evaluated. Tolerance and variance inflation factors (VIF) statistics were examined to assess multicollinearity.

The original priori power calculation was based on the primary bivariate correlation analyses rather than the multivariable regression model; therefore, the regression analysis was considered exploratory and interpreted accordingly. All statistical tests were two-sided, and statistical significance was set at $p < 0.05$.

Results

Participant characteristics

A total of 73 female university students were included in the analysis. Participants had a mean age of 19.6 ± 1.5 years, mean BMI of 21.5 ± 3.0 kg/m², and mean body fat percentage (BF%) of $27.8 \pm 4.6\%$. Estimated cardiorespiratory fitness (VO₂max) averaged 38.5 ± 3.1 mL·kg⁻¹·min⁻¹, while mean handgrip strength and flexibility were 41.0 ± 9.1 kg and 36.7 ± 7.0 cm, respectively. Most participants were classified as normal weight (74.0%, $n = 54$), while 15.1% ($n = 11$) were underweight, 9.6% ($n = 7$) were overweight, and 1.4% ($n = 1$) had obesity.

Total physical activity averaged 3837.9 ± 3846.5 MET-min/week, although substantial interindividual variability was observed. Based on the three-level IPAQ classification, 32 participants (43.8%) were classified as having high physical activity, 38 (52.1%) as moderate, and 3 (4.1%) as low physical activity. Mean daily sitting time was 6.8 ± 3.0 h/day. The mean global PSQI score was 6.3 ± 3.2 , with 40 participants (54.8%) classified as having poor sleep quality (PSQI > 5) and 33 (45.2%) as having good sleep quality. Mean stress, anxiety, and depression scores were 13.3 ± 10.1 , 9.8 ± 10.3 , and 6.9 ± 9.8 , respectively. Forty participants (54.8%) were classified within the normal range for stress, 39 (53.4%) for anxiety, and 53 (72.6%) for depression (Table 1).

Table 1
Characteristics of the study participants (N = 73)

Characteristics	M ± SD
Age (years)	19.6 ± 1.5
Body mass (kg)	54.9 ± 9.4
Height (cm)	159.7 ± 5.9
BMI (kg/m ²)	21.5 ± 3.0
Body fat (%)	27.8 ± 4.6
Estimated VO ₂ max (mL·kg ⁻¹ ·min ⁻¹)	38.5 ± 3.1
Handgrip strength (kg)	41.0 ± 9.1
Flexibility (cm)	36.7 ± 7.0
Total physical activity (MET-min/week)	3837.9 ± 3846.5
Sitting time (h/day)	6.8 ± 3.0
Global PSQI score	6.3 ± 3.2
Stress score	13.3 ± 10.1
Anxiety score	9.8 ± 10.3
Depression score	6.9 ± 9.8
Poor sleep quality (n %)	40 (54.8)
Good sleep quality (n %)	33 (45.2)

Values are presented as mean (M) ± Stander Deviation (SD) unless otherwise indicated. VO₂max, maximal oxygen uptake; MET, metabolic equivalent; PSQI, Pittsburgh Sleep Quality Index.

Associations among body composition, physical fitness, and behavioral factors

Spearman correlation analysis demonstrated a strong positive association between BMI and BF% ($\rho = 0.688$, $p < 0.001$). Higher BF% was also associated with lower estimated VO₂max ($\rho = -0.248$, $p = 0.035$) and greater daily sitting time ($\rho = 0.237$, $p = 0.043$). Handgrip strength was positively associated with flexibility ($\rho = 0.266$, $p = 0.023$). No significant associations were observed between total physical activity expressed as MET-min/week and BMI, BF%, estimated VO₂max, handgrip strength, or flexibility (all $p > 0.05$).

Daily sitting time was positively associated with stress ($\rho = 0.239$, $p = 0.042$), whereas its associations with anxiety and depression did not reach statistical significance.

Sleep quality and psychological status

Global PSQI score was positively associated with all three dimensions of psychological status. Poorer sleep quality was associated with higher stress ($p = 0.532$, $p < 0.001$), anxiety ($p = 0.507$, $p < 0.001$), and depression scores ($p = 0.332$, $p = 0.004$). The psychological variables were also strongly interrelated. Stress was positively associated with anxiety ($p = 0.766$, $p < 0.001$) and depression ($p = 0.638$, $p < 0.001$), while anxiety was positively associated with depression ($p = 0.735$, $p < 0.001$). In contrast, global PSQI score was not significantly associated with estimated VO_{2max} , handgrip strength, flexibility, total physical activity, or sitting time (all $p > 0.05$) (Table 2).

Table 2

Selected Spearman correlations among physiological, behavioral, sleep, and psychological variables

Variables	Spearman's (ρ)	p value
BMI – BF%	0.688	< 0.001
BF% – estimated VO_{2max}	-0.248	0.035
BF% – sitting time	0.237	0.043
Handgrip strength – flexibility	0.266	0.023
Sitting time – stress	0.239	0.042
PSQI – stress	0.532	< 0.001
PSQI – anxiety	0.507	< 0.001
PSQI – depression	0.332	0.004
Stress – anxiety	0.766	< 0.001
Stress – depression	0.638	< 0.001
Anxiety – depression	0.735	< 0.001
<i>Note: Values are Spearman's rank-order correlation coefficients (ρ). Higher PSQI scores indicate poorer sleep quality. Statistical significance was set at a two-sided $p < 0.05$. BMI, body mass index; BF%, body fat percentage; VO_{2max}, maximal oxygen uptake.</i>		

Cardiorespiratory fitness and body fat

Participants classified in the higher cardiorespiratory fitness group had significantly lower BF% than those classified in the lower fitness group. Median BF% was 26.15% (IQR 24.13–29.20) in the higher-fitness group ($n = 30$), compared with 28.90% (IQR 25.65–31.40) in the lower-fitness group ($n = 43$; Mann–Whitney $U = 445.5$, $p = 0.026$). This group comparison was consistent with the inverse correlation observed between estimated VO_{2max} and BF%.

Physical activity level and sleep quality

Because only three participants were classified in the low physical activity category, categorical comparisons were restricted to participants with moderate or high physical activity. Among participants with high physical activity, 19 of 32 (59.4%) had poor sleep quality compared with 20 of 38 (52.6%) participants with moderate physical activity. There was no significant association between physical activity category and sleep-quality classification ($\chi^2(1) = 0.32, p = 0.572$). Thus, physical activity category was not significantly associated with the prevalence of poor sleep quality in this sample.

Multivariable associations with sleep quality

The multivariable linear regression model was statistically significant, $F(10, 62) = 5.56, p < 0.001$, explaining 47.3% of the variance in global PSQI score ($R^2 = 0.473$; adjusted $R^2 = 0.388$). After simultaneous adjustment for physiological, behavioral, and psychological variables, stress was the only significant independent correlate of poorer sleep quality ($B = 0.148, 95\% \text{ CI } 0.056\text{--}0.239; \beta = 0.469, p = 0.002$). BF% showed a positive association with global PSQI score that did not reach statistical significance ($B = 0.197, 95\% \text{ CI } -0.017 \text{ to } 0.412; \beta = 0.282, p = 0.071$). No other variables were independently associated with global PSQI score (all $p > 0.05$; Table 3).

Table 3
Multiple linear regression examining factors associated with global PSQI score

Predictor	B	95% CI for B	β	<i>p</i> value
BMI	-0.181	-0.501 to 0.139	-0.172	0.264
BF%	0.197	-0.017 to 0.412	0.282	0.071
Estimated VO ₂ max	0.092	-0.114 to 0.297	0.090	0.376
Handgrip strength	0.018	-0.052 to 0.088	0.051	0.611
Flexibility	0.071	-0.018 to 0.161	0.157	0.116
Total physical activity	< 0.001	<-0.001 to < 0.001	0.037	0.699
Sitting time	-0.118	-0.331 to 0.095	-0.111	0.273
Stress	0.148	0.056 to 0.239	0.469	0.002
Anxiety	0.083	-0.019 to 0.185	0.269	0.108
Depression	-0.043	-0.148 to 0.061	-0.132	0.412

Model: $F(10, 62) = 5.56, p < 0.001; R^2 = 0.473$; adjusted $R^2 = 0.388$.

Abbreviations: B, unstandardized regression coefficient; CI, confidence interval; β , standardized regression coefficient; BMI, body mass index; BF%, body fat percentage; VO₂max, maximal oxygen uptake; PSQI, Pittsburgh Sleep Quality Index.

Note: The dependent variable was global PSQI score, with higher scores indicating poor sleep quality. Total physical activity was expressed as MET-min/week. Statistical significance was set at a two-sided p

< 0.05.

Discussion

The present study examined the relationships among physical activity, sedentary behavior, health-related physical fitness, body composition, sleep quality, and psychological status in Saudi female university students. The main finding was that poorer sleep quality was associated with higher stress, anxiety, and depression, while stress showed the strongest association and was the only factor independently associated with global PSQI score after adjustment for physiological, behavioral, and psychological variables. In contrast, physical activity and estimated CRF were not associated with sleep quality. Higher BF% was associated with lower estimated CRF and greater sitting time, while greater sitting time was also associated with higher stress.

The relationship between sleep quality and psychological status observed in the present study is consistent with recent evidence from Saudi university students. A recent study of 508 Saudi university students using the PSQI and DASS-21 similarly reported significant associations between poor sleep quality and stress, anxiety, and depression, with stress showing the strongest association with poor sleep [38]. These findings support the close relationship between sleep quality and psychological status observed in the present study.

Several physiological mechanisms may contribute to the particularly strong association between stress and sleep. Psychological stress activates the hypothalamic-pituitary-adrenal (HPA) axis and autonomic nervous system, increasing neuroendocrine and physiological arousal that may interfere with normal sleep regulation [39, 40]. HPA-axis activity is closely linked to the sleep-wake cycle, with cortisol secretion following a circadian pattern; conversely, sleep disruption may alter HPA-axis and autonomic responses to subsequent stressors [39–41]. This reciprocal interaction provides a plausible physiological explanation for the strong stress-sleep relationship observed in the present study. Nevertheless, although stress remained independently associated with poorer sleep quality after adjustment for the other variables, the cross-sectional design does not establish whether greater stress contributed to poorer sleep, poorer sleep increased stress, or both processes occurred concurrently.

Anxiety and depression were also associated with poorer sleep quality in the bivariate analyses but did not remain independently associated with PSQI score in the multivariable model. This may partly reflect the strong intercorrelations among stress, anxiety, and depression observed in the present sample. Their shared variance when entered simultaneously into the model may have reduced the unique contribution of anxiety and depression to sleep quality. Thus, the findings suggest that stress was the psychological dimension most strongly and independently associated with sleep quality in this sample, rather than indicating that anxiety and depression were unrelated to sleep.

Neither total physical activity nor estimated CRF was significantly associated with sleep quality. Although exercise is generally associated with favorable sleep outcomes, findings in adolescents and young adults have been less consistent than those reported in older or clinical populations [42]. The

relationship may also depend on exercise characteristics such as timing, intensity, and duration. Exercise can influence physiological processes involved in sleep regulation, including cortisol and melatonin rhythms and core body temperature, with responses varying according to exercise timing and intensity [43]. In the present study, most participants reported moderate or high physical activity, with only three classified as having low activity, potentially limiting the variability required to detect an association with sleep. Moreover, the IPAQ-SF quantifies overall activity volume but does not characterize exercise timing or other features that may influence sleep.

The absence of an association between estimated CRF and sleep quality is consistent with previous findings in healthy populations. Osailan et al. (2021) found no association between directly measured $\text{VO}_{2\text{peak}}$ and either global PSQI score or its individual components in apparently healthy adults [44]. More recently, Kandel et al. (2026) similarly found no association between estimated $\text{VO}_{2\text{max}}$ and sleep quality in healthy young adults using the Queens College Step Test and PSQI [45]. In contrast, the FIT-AGEING study reported that higher directly measured $\text{VO}_{2\text{max}}$ was associated with better objective and subjective sleep among sedentary middle-aged adults, suggesting that the CRF-sleep relationship may differ according to age, baseline activity or fitness status, and population characteristics [46]. In the present young and relatively active sample, psychological stress showed a stronger relationship with PSQI score than estimated CRF, suggesting that perceived sleep quality may have been more closely related to psychological status than aerobic fitness. Additionally, the relatively homogeneous sample and use of a submaximal field test to estimate CRF may have reduced the ability to detect an association.

Although estimated CRF was unrelated to sleep quality, it was inversely associated with BF%, and participants with higher estimated CRF had lower BF%. This finding is consistent with previous evidence showing inverse associations between CRF and measures of adiposity, including body fat percentage [47]. Physiologically, greater aerobic fitness reflects integrated adaptations in oxygen delivery and utilization across the cardiovascular and skeletal-muscle systems [48]. However, the relationship may also partly reflect the way aerobic fitness is expressed. In the present study, estimated $\text{VO}_{2\text{max}}$ was expressed relative to total body mass ($\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$); consequently, greater fat mass can contribute to a lower relative $\text{VO}_{2\text{max}}$, and ratio scaling to total body mass may introduce body-size-related bias [49, 50]. The relationship should therefore not be interpreted as unidirectional: higher CRF may accompany a more favorable body-composition profile, while greater adiposity may also contribute to lower relative $\text{VO}_{2\text{max}}$ values.

Greater sitting time was associated with both higher BF% and greater stress. University students are known to accumulate substantial sedentary time, with a systematic review and meta-analysis estimating approximately 7.3 h/day from self-report and 9.8 h/day from accelerometry [51]. Prolonged sitting is characterized by low energy expenditure and reduced skeletal-muscle activity and, when accumulated excessively, may contribute to adverse metabolic adaptations and greater adiposity [52, 53]. The relationship with stress is less clearly established. Earlier systematic evidence found inconsistent associations between overall sedentary time and stress, particularly when sedentary behavior was self-

reported [54]. More recent evidence continues to emphasize that the relationship may depend on the type and context of sedentary behavior rather than sitting time alone [55]. Therefore, the positive sitting-stress association observed in the present study warrants further investigation using objective measures capable of distinguishing prolonged sitting, screen-based sedentary behavior, and interruptions in sedentary time.

Taken together, the findings suggest that the relationships among lifestyle behaviors, physical fitness, sleep, and psychological status are not uniform. Psychological stress was most closely associated with sleep quality, whereas estimated CRF and sedentary behavior showed stronger relationships with body composition. This distinction is relevant to women's health promotion because increasing physical activity alone may not address all dimensions of health. Recent systematic evidence in university students indicates that higher physical activity is generally associated with more favorable stress and mental-health outcomes, particularly when accompanied by other healthy behaviors such as adequate sleep and lower sedentary behavior [56]. Accordingly, university health initiatives for young women may benefit from an integrated approach incorporating physical activity and fitness promotion, reduction of prolonged sitting, sleep education, and stress-management strategies.

Strengths and limitations

A strength of this study was the simultaneous assessment of lifestyle behaviors, sleep quality, psychological status, body composition, and multiple components of health-related physical fitness. Objective physical assessments were combined with validated self-report instruments, allowing behavioral, physiological, and psychological characteristics to be considered within the same study. Several limitations should also be acknowledged. The cross-sectional design precludes causal or temporal interpretation, and convenience sampling from a single university setting limits generalizability. Physical activity and sitting time were self-reported, estimated CRF was derived from a submaximal field test rather than direct measurement of $\text{VO}_{2\text{max}}$, and BF% was estimated using bioelectrical impedance analysis. In addition, the internal consistency of the PSQI was modest in the present sample. Finally, the original sample-size calculation was based on the primary correlational analyses rather than the 10-predictor regression model; therefore, the multivariable analysis should be regarded as exploratory and may have been insufficiently powered to identify small independent associations.

Conclusion

Poorer sleep quality among Saudi female university students was most strongly associated with psychological status, particularly stress. Physical activity and estimated CRF were not associated with sleep quality; however, lower estimated CRF and greater sitting time were associated with less favorable body composition, while greater sitting time was also associated with higher stress. These findings highlight the interrelationships among psychological, behavioral, and physiological dimensions of women's health and support an integrated approach incorporating sleep and stress management alongside physical activity, physical fitness, and sedentary-behavior reduction.

Abbreviations

BF%: Body fat percentage

BMI: Body mass index

CRF: Cardiorespiratory fitness

DASS-21: Depression Anxiety Stress Scales-21

IPAQ-SF: International Physical Activity Questionnaire–Short Form

MET: Metabolic equivalent

PA: Physical activity

PSQI: Pittsburgh Sleep Quality Index

VO₂max: Maximal oxygen uptake

Declarations

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Authors' contributions

AM conceptualized and designed the study, developed the methodology, supervised data collection, performed the statistical analyses, interpreted the findings, and drafted and revised the manuscript. RH, MA, RA, MAI, HA, SA, GA, and RBS contributed to data collection. All authors read and approved of the final manuscript.

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Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

Ethical approval was obtained from the Institutional Review Board of Princess Nourah bint Abdulrahman University (IRB No. 26-0529). Written informed consent was obtained from all participants prior to participation. All procedures were conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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