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Original Research Article

Beyond BMI: Association of Sleep Quality, Body Composition, and Cardiorespiratory Fitness among Apparently Healthy Young Adults

Annu Ankita[1], Nidhi Singh[2], Mo. Shaqib[3]

[1]Assistant Professor, Department of Physiology, Era Lucknow Medical College, Lucknow, UP, India

[2]Assistant Professor, Department of Physiology, Era Lucknow Medical College, Lucknow, UP, India

[3]Post. Senior Resident, Department of Physiology, Dr. B.S. Kushwah Institute of Medical Science, Kanpur, UP, India

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Corresponding author: Dr. Annu Ankita

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Abstract

Background: Poor sleep is becoming increasingly common among young adults and may adversely affect body composition and physical fitness. Since BMI alone does not accurately reflect metabolic health, assessing body composition and cardiorespiratory fitness may provide better health information.

Objective: To evaluate the association of sleep quality with body composition and cardiorespiratory fitness among apparently healthy young adults.

Materials and Methods: A cross-sectional study was conducted among 180 healthy adults aged 18–30 years. Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI). Body composition was measured by bioelectrical impedance analysis, and cardiorespiratory fitness was assessed using the Queens College Step Test to estimate VO_2max. Data were analysed using the independent t-test, Chi-square test, Pearson's correlation, and multiple linear regression. A p-value <0.05 was considered statistically significant.

Results: Of the 180 participants, 104 (57.8%) had poor sleep quality. Poor sleepers had significantly higher BMI, body fat percentage, visceral fat, and waist circumference, while skeletal muscle percentage and estimated VO_2max were significantly lower ($p<0.05$). PSQI score showed a positive correlation with body fat percentage and visceral fat and a negative correlation with VO_2max. Body fat percentage and VO_2max were independent predictors of poor sleep quality.

Conclusion: Poor sleep quality was associated with adverse body composition and lower cardiorespiratory fitness in apparently healthy young adults. Assessing sleep quality along with body composition and fitness may help identify individuals at increased risk of future cardiometabolic disorders.

Keywords: Sleep Quality, PSQI, Body Composition, Cardiorespiratory Fitness, VO_2Max, Young Adults.

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Introduction

Sleep is an essential physiological process that is important for maintaining physical, mental, and metabolic health. Good-quality sleep supports tissue repair, hormone regulation, immune function, memory, learning, and emotional well-being. Inadequate or poor-quality sleep has become a major public health concern because it is associated with obesity, insulin resistance, hypertension, type 2 diabetes mellitus, cardiovascular disease, and impaired cognitive function [1,2].

Poor sleep quality has become increasingly common among young adults due to rapid lifestyle changes. Academic pressure, prolonged screen time, excessive smartphone use, irregular sleep schedules, unhealthy dietary habits, reduced physical activity, and psychological stress have all contributed to disturbed sleep in this age group [3,4]. Although many young adults appear healthy, persistent poor sleep may lead to early metabolic and physiological changes that increase the risk of future cardio-metabolic diseases.

Body mass index (BMI) is the most widely used measure to assess overweight and obesity. However, BMI has important limitations because it does not differentiate fat mass from lean body mass or indicate fat distribution. Individuals with the same BMI may have markedly different body fat percentages and muscle mass, resulting in different metabolic risk profiles [5]. Therefore, BMI alone may not accurately identify individuals at increased risk of metabolic disorders. Assessment of body composition provides a more detailed evaluation of health than BMI alone. Bioelectrical impedance analysis (BIA) is a simple, non-invasive, and reliable technique that estimates body fat percentage, skeletal muscle mass, visceral fat, fat-free mass, and total body water [6]. Increased body fat, particularly visceral fat, has been linked to insulin resistance, chronic inflammation, dyslipidaemia, and cardiovascular disease, whereas higher skeletal muscle mass is associated with better metabolic health [7,8].

Cardiorespiratory fitness is another important indicator of overall health. It reflects the ability of the cardiovascular and respiratory systems to supply oxygen to working muscles during physical activity. Maximal oxygen uptake (VO_2max) is considered the standard measure of cardiorespiratory fitness and is a strong predictor of cardiovascular health and overall mortality [9]. Individuals with better cardiorespiratory fitness generally have lower body fat, improved insulin sensitivity, better autonomic function, and a lower risk of chronic diseases [10].

Recent studies suggest that sleep quality, body composition, and cardiorespiratory fitness are closely interrelated. Poor sleep can alter the secretion of hormones such as leptin, ghrelin, cortisol, growth hormone, and insulin, leading to increased appetite, fat accumulation, reduced muscle recovery, and impaired glucose metabolism [11,12]. Inadequate sleep may also reduce physical activity, increase fatigue, and lower exercise performance, resulting in reduced cardiorespiratory fitness. Conversely, regular physical activity and higher fitness levels have been shown to improve sleep quality by promoting autonomic balance and healthy circadian rhythms [13,14].

Although many studies have examined the relationship between sleep and obesity, fewer studies have simultaneously evaluated sleep quality, body composition, and cardiorespiratory fitness in apparently healthy young adults. Most available studies have relied mainly on BMI, which may not adequately reflect body fat distribution or physical fitness [15]. Moreover, evidence from the Indian population remains limited despite the increasing prevalence of sedentary lifestyles, obesity, and sleep disturbances among young adults [16].

Understanding the relationship between sleep quality, body composition, and cardiorespiratory fitness may help identify young adults at increased risk of future metabolic and cardiovascular diseases. Early recognition of these modifiable risk factors can support preventive strategies focused on improving sleep hygiene, promoting regular physical activity, and maintaining healthy body composition. Therefore, the present study was undertaken to evaluate the association of sleep quality with body composition and cardiorespiratory fitness among apparently healthy young adults. The findings may provide useful evidence for incorporating sleep assessment into routine health evaluation and support lifestyle interventions aimed at improving long-term health outcomes.

Materials and Methods

Study Design and Participants: A hospital-based cross-sectional observational study was conducted in the Department of Physiology of a tertiary care teaching hospital over 18 months after approval from the Institutional Ethics Committee. The study followed the ethical principles of the Declaration of Helsinki, and written informed consent was obtained from all participants.

A total of 180 apparently healthy young adults aged 18–30 years were enrolled using convenience sampling. Undergraduate and postgraduate students, interns, and hospital staff fulfilling the eligibility criteria were included.

Participants with hypertension, diabetes mellitus, cardiovascular, respiratory, thyroid, renal, neurological or psychiatric disorders, pregnancy, acute illness, diagnosed sleep disorders, use of medications affecting sleep, physical disability preventing exercise testing, or professional athletic training were excluded.

Study Procedure: Participants attended the physiology laboratory in the morning after an overnight fast. They were instructed to avoid caffeine, alcohol, smoking, and vigorous physical activity for 24 hours before assessment. Demographic details, lifestyle information, anthropometric measurements, sleep quality, body composition, and cardiorespiratory fitness were recorded using a structured case record form.

Anthropometric Measurements: Height and weight were measured using standard procedures, and body mass index (BMI) was calculated as weight (kg)/height² (m²). Waist and hip circumferences were measured, and waist-to-hip ratio (WHR) was calculated.

Assessment of Sleep Quality: Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a validated questionnaire consisting of seven components with a global score ranging from 0 to 21. Participants with a PSQI score ≤ 5 were classified as good sleepers, whereas those with a PSQI score >5 were classified as poor sleepers.

Body Composition Assessment: Body composition was assessed using a validated bioelectrical impedance analyser (BIA). The parameters recorded included body fat percentage, skeletal muscle percentage, fat-free mass, total body water, visceral fat level, and basal metabolic rate. Participants were assessed according to standard manufacturer guidelines.

Assessment of Cardiorespiratory Fitness: Cardiorespiratory fitness was evaluated using the Queens College Step Test. Participants performed a 3-minute step test on a 41.3-cm bench at a stepping rate of 24 steps/minute for males and 22 steps/minute for females. Recovery heart rate was measured immediately after exercise, and VO_2max was estimated using standard gender-specific equations.

Outcome Measures: The primary outcome was the association between sleep quality and cardiorespiratory fitness. Secondary outcomes included the association of sleep quality with body composition parameters, comparison of body composition and VO_2max between good and poor sleepers, and correlation of PSQI score with body composition and cardiorespiratory fitness.

Statistical Analysis: Data were analysed using IBM SPSS Statistics version 29.0. Continuous variables were expressed as mean ±standard deviation (SD) and categorical variables as frequency and percentage. Comparisons between groups were performed using the independent Student's t-test or Chi-square test, as appropriate. Pearson's correlation analysis and multiple linear regression were used to determine the association between sleep quality, body composition, and cardiorespiratory fitness. A p-value <0.05 was considered statistically significant.

Ethical Considerations: The study protocol was approved by the Institutional Ethics Committee before commencement. Participation was voluntary, and written informed consent was obtained from all participants.

Results

A total of 180 apparently healthy young adults were included in the study. All participants completed the Pittsburgh Sleep Quality Index (PSQI), body composition assessment, and cardiorespiratory fitness testing. There were no missing data; therefore, all 180 participants were included in the final analysis.

Baseline Characteristics: The mean age of the study participants was 23.4 ±2.8 years (range: 18–30 years). Of the 180 participants, 95 (52.8%) were males and 85 (47.2%) were females. The overall mean BMI was 23.1 ±3.4 kg/m².

Table 1: Baseline Characteristics of Study Participants (N = 180)

Variable	Value
Age (years), mean ±SD	23.4 ±2.8
Male, n (%)	95 (52.8)
Female, n (%)	85 (47.2)
Height (cm), mean ±SD	166.8 ±8.9
Weight (kg), mean ±SD	64.2 ±11.5
BMI (kg/m²), mean ±SD	23.1 ±3.4
Waist circumference (cm), mean ±SD	82.6 ±9.4
Hip circumference (cm), mean ±SD	94.3 ±8.1
Waist–Hip Ratio	0.88 ±0.06

Sleep Quality: Based on the PSQI score, 76 participants (42.2%) were classified as good sleepers (PSQI ≤5), whereas 104 participants (57.8%) were classified as poor sleepers (PSQI >5). The mean global PSQI score of the study population was 6.4 ±2.3.

Table 2: Distribution of Sleep Quality

Sleep Quality	Number	Percentage (%)
Good sleepers	76	42.2
Poor sleepers	104	57.8
Total	180	100

Comparison of Body Composition: Poor sleepers demonstrated significantly higher BMI, body fat percentage, visceral fat level, and waist circumference than good sleepers. Skeletal muscle percentage was significantly lower among poor sleepers.

Table 3: Comparison of Body Composition between Good and Poor Sleepers

Variable	Good Sleepers (n=76)	Poor Sleepers (n=104)	p-value
BMI (kg/m²)	22.1 ±2.8	23.8 ±3.6	0.002
Body fat (%)	23.6 ±6.1	28.5 ±7.3	<0.001
Skeletal muscle (%)	39.8 ±5.4	36.4 ±5.8	<0.001
Visceral fat level	6.2 ±2.3	8.1 ±2.9	<0.001
Fat-free mass (kg)	48.6 ±8.4	46.3 ±8.7	0.048
Total body water (%)	55.8 ±5.2	52.7 ±5.5	0.001
Waist circumference (cm)	79.8 ±8.1	84.7 ±9.6	0.001

Comparison of Cardiorespiratory Fitness: Estimated VO_2max was significantly lower in poor sleepers. Recovery heart rate was significantly higher among poor sleepers, indicating reduced cardiorespiratory fitness.

Table 4. Comparison of Cardiorespiratory Fitness

Variable	Good Sleepers	Poor Sleepers	p-value
VO_2max (mL/kg/min)	45.8 ±4.6	40.9 ±4.8	<0.001
Resting heart rate (beats/min)	71.3 ±7.4	76.1 ±8.2	<0.001
Recovery heart rate (beats/min)	104.6 ±11.2	116.8 ±12.5	<0.001
Systolic BP (mmHg)	116.2 ±8.4	118.5 ±9.2	0.084
Diastolic BP (mmHg)	74.3 ±6.5	75.9 ±7.2	0.112

Correlation Analysis: Pearson correlation analysis showed that increasing PSQI scores (indicating poorer sleep quality) were significantly associated with adverse body composition and lower cardiorespiratory fitness.

Table 5. Correlation of PSQI Score with Study Variables

Variable	Correlation coefficient (r)	p-value
BMI	0.28	<0.001
Body fat (%)	0.43	<0.001
Visceral fat	0.38	<0.001
Skeletal muscle (%)	-0.35	<0.001
Waist circumference	0.31	<0.001
VO_2max	-0.51	<0.001
Recovery heart rate	0.46	<0.001

The strongest inverse correlation was observed between PSQI score and VO_2max ($r = -0.51$), suggesting that poorer sleep quality was associated with reduced cardiorespiratory fitness.

Multiple Linear Regression Analysis: A multiple linear regression model was constructed with PSQI score as the dependent variable and age, sex, BMI, body fat percentage, visceral fat level, and VO_2max as independent variables.

Table 6: Multiple Linear Regression Analysis

Predictor	Standardized β	p-value
Age	0.07	0.274
Sex	0.06	0.318
BMI	0.10	0.092
Body fat (%)	0.29	<0.001
Visceral fat	0.18	0.014
VO_2max	-0.37	<0.001

The regression model explained approximately 41% of the variance in PSQI score (Adjusted $R^2 = 0.41$). Body fat percentage and VO_2max emerged as the strongest independent predictors of sleep quality.

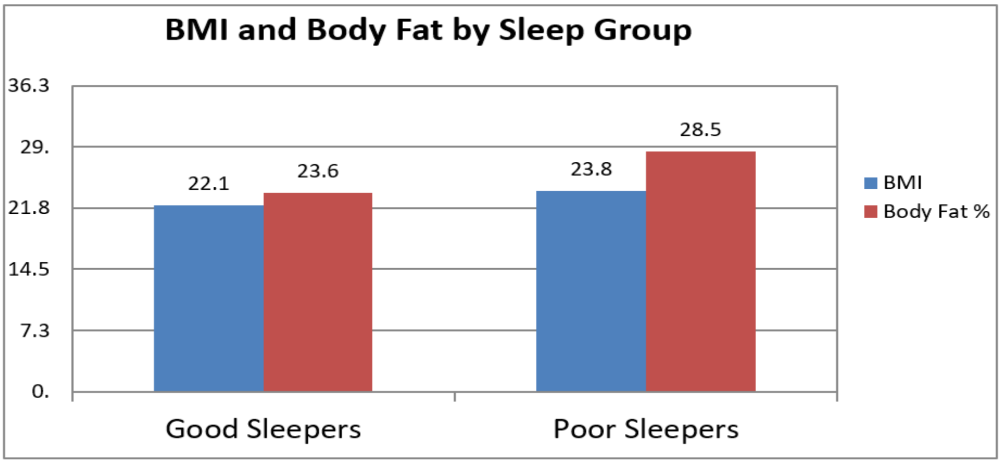

Figure 1: Comparison of Body Mass Index (BMI) and Body Fat Percentage between Good and Poor Sleepers

Figure 1 shows the comparison of mean BMI and body fat percentage between participants with good sleep quality (PSQI ≤5) and poor sleep quality (PSQI >5). Poor sleepers had higher mean BMI and body fat percentage than good sleepers.

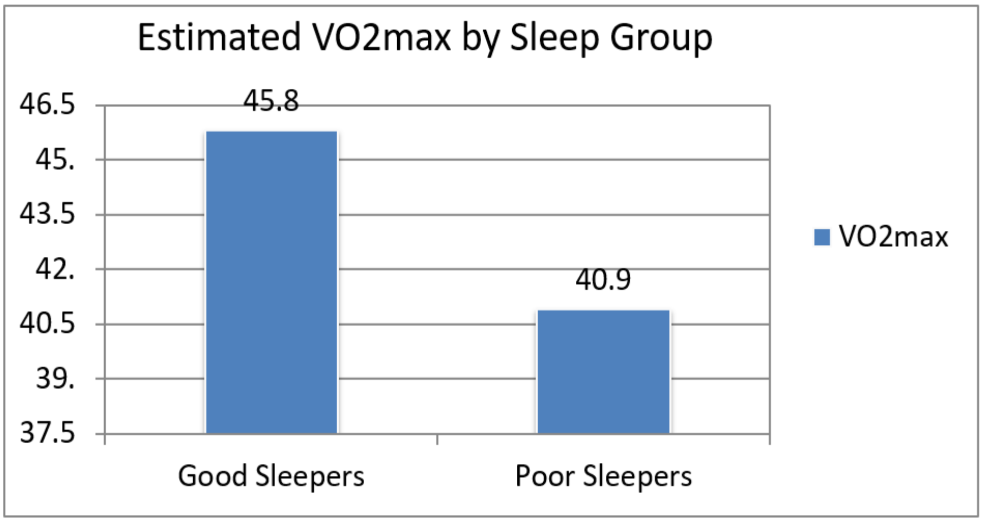

Figure 2: Comparison of Estimated VO_2max between Good and Poor Sleepers

Figure 2 compares the mean estimated VO_2max between good and poor sleepers. Participants with poor sleep quality had significantly lower estimated VO_2max, indicating reduced cardiorespiratory fitness.

Discussion

The present study evaluated the association of sleep quality with body composition and cardiorespiratory fitness among apparently healthy young adults. More than half of the participants (57.8%) had poor sleep quality, indicating that sleep disturbance is common in this age group. Similar findings have been reported by Hershner and Chervin [1] and Itani et al. [2], who observed a high prevalence of poor sleep among young adults due to academic stress, prolonged screen time, sedentary lifestyle, and irregular sleep habits. Poor sleepers in the present study had significantly higher BMI, body fat percentage, visceral fat level, and waist circumference than good sleepers. These findings are consistent with previous studies showing that inadequate sleep is associated with increased adiposity and central obesity [3,4]. Sleep restriction may alter appetite-regulating hormones such as leptin and ghrelin, increase cortisol secretion, and reduce insulin sensitivity, leading to increased energy intake and fat accumulation [5,6]. However, our study also showed that body composition parameters were more strongly associated with sleep quality than BMI alone, highlighting the limitations of BMI in assessing metabolic health. Body fat percentage and visceral fat demonstrated significant positive correlations with PSQI score, whereas skeletal muscle percentage showed a negative correlation. Similar observations have been reported by Maruszczak et al. [7], who found that poor sleep quality was associated with increased body fat and reduced muscle mass in healthy adults. These findings suggest that poor sleep may contribute to unfavourable changes in body composition even before the development of obesity or metabolic disease.

An important finding of the present study was the significantly lower estimated VO_2max among poor sleepers. PSQI score was negatively correlated with VO_2max, and regression analysis identified VO_2max as an independent predictor of sleep quality. These findings agree with the systematic review by Kredlow et al. [8], which reported that individuals with better cardiorespiratory fitness generally have better sleep quality.

Similarly, Chennaoui et al. [9] suggested that regular physical activity improves autonomic function, reduces stress, and enhances sleep quality. Poor sleepers also showed higher recovery heart rate after exercise, indicating reduced cardiorespiratory fitness. Sleep deprivation is known to increase sympathetic activity and reduce parasympathetic recovery, resulting in impaired cardiovascular adaptation to exercise [10]. In contrast, blood pressure did not differ significantly between the two groups. Similar findings have been reported in studies involving healthy young adults, where metabolic changes were evident before the development of hypertension [11].

The present study supports the concept that assessment of body composition and cardiorespiratory fitness provides a better evaluation of health than BMI alone.

Individuals with a normal BMI may still have increased body fat, lower muscle mass, and poor aerobic fitness, placing them at increased risk of future cardiometabolic disease. Therefore, assessment of sleep quality together with body composition and fitness may help identify high-risk individuals at an early stage.

A major strength of this study is the simultaneous assessment of sleep quality, body composition, and cardiorespiratory fitness using validated methods.

However, the cross-sectional design limits causal interpretation. Sleep quality was assessed using a self-reported questionnaire, and VO_2max was estimated using a submaximal exercise test rather than direct laboratory measurement. Future longitudinal studies with objective sleep assessment techniques are recommended to confirm these findings.

Conclusion

In conclusion, poor sleep quality was associated with increased body fat, greater visceral adiposity, reduced skeletal muscle percentage, and lower cardiorespiratory fitness among apparently healthy young adults. These findings suggest that body composition analysis and cardiorespiratory fitness assessment provide valuable information beyond BMI and may facilitate early identification of individuals at risk for future cardiometabolic disorders.

Limitations: This study was cross-sectional; therefore, a causal relationship could not be established. Sleep quality was assessed using the PSQI, and cardiorespiratory fitness was estimated by the Queens College Step Test instead of direct measurements. The study was conducted at a single centre, which may limit the generalizability of the findings.

Future Directions: Future multicentre longitudinal studies using objective sleep assessment and direct measurement of VO_2max are needed. Lifestyle intervention studies focusing on sleep, physical activity, and healthy diet may further clarify their effects on body composition and cardiorespiratory fitness.

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