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Article

The association between cardiorespiratory fitness and reported physical activity with sleep quality in apparently healthy adults: a cross-sectional study.

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Abstract: Background: Recently, cardiorespiratory fitness (CRF) has been postulated as an adverse health outcome related to poor sleep quality. However, studies investigating the relationship between CRF with subjective sleep quality index are scarce. Thus, the current study aimed to investigate the association between CRF and Pittsburgh sleep quality index (PSQI) in apparently healthy people. The secondary aim was to investigate the association between reported physical activities (PA) and PSQI. Methods: 33 apparently healthy male participants volunteered to participate. CRF (VO2 peak) was measured via cardiopulmonary exercise testing on a treadmill. A short form of the International physical activity questionnaire (IPAQ) was used to measure PA, and PSQI was used for sleep quality index. Results: There was no correlation between CRF and PSQI total score or any component of the PSQI. Also, there was no correlation between IPAQ and PSQI total score. Categorical data analysis of the two questionnaires revealed that 45.5% of the participants reported low physical activity and poor sleep quality. Conclusions: There was no association between CRF, reported PA with subjective sleep quality index. The use of objective tools for assessing the quality and quantity of sleep should be recommended for future studies as it may clarify the association between CRF and sleep quality.

Keywords: cardiorespiratory fitness; VO2 peak; sleep quality, physical activity

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1. Introduction

Poor sleep quality is considered a public health burden and has been associated with many health problems [1]. Fatigue, tiredness, and daytime sleepiness have been reported by those who experience short sleep duration [2]. It has also been found that poor sleep quality has been linked with many adverse health outcomes, including hypertension [3], increased risk of diabetes [4], risk of cardiovascular disease (CVD) [5], and poor cardiorespiratory fitness (CRF) [6].These health issues may eventually be attributed to the increased risk of mortality among people with poor or disturbed sleep quality [7].

CRF refers to the heart, lungs, and circulatory system's ability to deliver oxygenated blood according to the metabolic demands required by the large group of muscles during a heavy dynamical activity [8]. CRF, also known as physical fitness, has been strongly associated with cardiovascular health. In this context, poor sleep quality has been suggested as a factor associated with reduced CRF [9].Having a reduced CRF may consequently lead to an increased risk of CVD [10]. Mounting evidence suggests that regular exercise has a favorable effect on sleep disturbances [11]. But the question about the relationship between CRF and sleep quality is debatable.

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Studies investigating the relationship between CRF with sleep quality are scarce. In a longitudinal study, CRF was not associated with sleep disturbances among women diagnosed with stress-related exhaustion disorder [12]. The association between CRF and sleep quality was reported among apparently healthy adolescents' girls [9]. In another longitudinal study, it was reported that middle-aged people tend to have lower CRF due to increased sleep complaints [13]. The inverse association between CRF (measured via VO2 peak) and insomnia was also reported [8]. Most of the previous studies measured CRF via estimation based on activity except for the latter one. Furthermore, previous studies focused on populations with clinical conditions, and to the best of knowledge, limited studies explored this relationship in healthy people using CRF (measured via VO2 peak) and sleep quality. Given the lack of studies in this area among healthy people with a standardized exercise testing protocol, this study's primary aim was to investigate the association between CRF and sleep quality in apparently healthy people. The secondary aim was to investigate the association between reported physical activity and sleep quality. It was hypothesized that CRF and reported physical activity would be inversely associated with sleep quality.

2. Materials and Methods

2.1. Participants

Thirty-three apparently healthy men (i.e., free from chronic disorders) recruited from Prince Sattam bin Abdulaziz University to participate in the study between December 2019 to December 2020. Inclusion criteria were as follow: apparently healthy above 18 years old. Exclusion criteria were: cardiovascular diseases, pulmonary diseases, or any other diseases that can limit their lung capacity (e.g. cold, flu), history of pulmonary surgery, neurological diseases, and any comorbidity incompatible with exercise testing as per the American College of Sports Medicine (ACSM) [14]. In addition, participants with a history of illness that limit physical exertion and recent surgery limiting physical work were excluded. According to the sample analysis performed using G*power software, a sample size of 32 subjects produces a two-sided 95% confidence interval with a width equal to 0.597 when the estimate of Spearman's rank correlation is 0.45, which was obtained from analyzing data from first 10 observations per the CRF (represented by the VO2 peak values) and sleep quality as reported on the Pittsburgh sleep quality index (PSQI). The study was approved by the ethical committee of the deanship of scientific research at Prince Sattam bin Abdulaziz University, and all participants signed informed consent before participation.

2.2. Protocol

Participants attended one visit to the exercise research lab atthe college of applied medical sciences at Prince Sattam bin Abdulaziz University. Once accepted to participate, a brief instruction of the study's protocol was given. Participants were instructed not to consume caffeinated drinks, eat or smoke at least 3 hours before the visit as per standard for exercise testing and training [15]. Before exercise testing, participants were asked to fill out the PSQI and the short form of the international physical activity questionnaire (IPAQ). After completing the questionnaires, height was measured to the nearest 0.5 cm using a stadiometer, and weight was measured using a weight analyzer (DETECTO, USA). Resting brachial blood pressure was taken using an electronic sphygmomanometer while seated in a chair with an armrest (Wollex Blood Pressure Monitor (ARM) /WXT-5902, Cigli Izmir, Turkey). Then, participants were fitted with a Polar heart rate monitor (polar H7) to monitor the heart rate during the test and an appropriate size face mask to cover the nose and mouth to measure inspired and expired gases analysis (see figure 1). Participants were given three minutes to measure resting heart rate and resting metabolic rate indicated by volumes of O2 consumption while seated, followed by the exercise tolerance test (ETT). At the end of the ETT, a recovery period was applied. All the tests were standardized to be performed during the day between 9:00 am to 2:00 pm.

2.3. Exercise tolerance test (ETT) protocol

Cardiopulmonary exercise testing (CPET) was conducted using COSMED Quark to analyze inspired and expired gases and was calibrated each day before testing. Before ETT, participants were instructed to minimize talking as much as possible unless asked by the examiner to answer questions during the test. The test was performed with the same protocol used in a previous study [16]. The face mask was connected to a breath-by-breath gas analysis COSMED Quark CPET. ETT was performed on a treadmill (HP Cosmos Mercury, Nussdoerf-Traunstien, Germany) using an individualized incremental test modified according to participants' physical abilities [17]. The test started at a speed of participant's preference (approximately between 3.5 – 4 kph) and 0% inclination. Once the test started, three minutes were given to serve as a familiarization/warming up phase with speed gradually increased to the participant's ability. At the start of the third minute of the familiarization phase, the participant was encouraged to reach maximum brisk walking speed. Then, after the third minute, the incremental test started with constant speed achieved (brisk walking) and 1% inclination. Throughout the ETT, speed remained constant and inclination was increased progressively every minute by 1%. Inspired and expired gases were analyzed breath-by-breath using COSMED Quark cardiopulmonary exercise testing (CPET) throughout the test and during the recovery period for a minimum of 5 minutes. If the participant reached volitional exhaustion and could no longer complete the test or any relative or absolute contraindication of ACSM criteria were met, the test was terminated [14]. Following termination of the test, participants were seated on a chair with an armrest while heart rate, inspired and expired gases. Blood pressure was continuously monitored during the recovery period for a minimum of six minutes or until vital signs regained normal ranges.

2.4. Outcome measures

2.4.1 Cardiorespiratory fitness (VO2 peak)

Peak oxygen uptake was recorded during treadmill ETT using a breath-by-breath gas analyzer. The inspired and expired gases data were collected and standardized to be averaged every five seconds. To minimize fluctuation of the data, final data collected were averaged for every 30 seconds of the VO2 sampling rate. VO2 peak was defined as the highest VO2 recorded during the test and was expressed as VO2 ml/kg/min. *2.4.2* Sleep quality

Sleep quality was assessed using PSQI. The questionnaire is valid, reliable consists of ten main questions comprising of 19 self-rated subjective questions[18]. The answers to the questions generate seven component scores. These components include sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, sleep medication use, and daytime dysfunction. These questions' scoring is dichotomized into the seven main components, with a range of 0 to 3 per each component, anda maximum score of 21 and a minimum of 0 for the whole questionnaire. A total score of < 5 indicates good overall sleep quality, whereas a total score ≥ of 5 indicates poor sleep quality [19].

2.4.3. Physical activity

Physical activity was assessed using the short form of IPAQ, which is known to be valid and mainly consists of seven questions [20]. The participants were instructed to answer questions in the form based on their level of physical activity in the last seven days before testing. This self-reported physical activity collects information about the duration and frequency of vigorous-intensity, moderate intensity, and light intensity activities performed in the last seven days. Overall estimation of metabolic equivalents (MET) (1 METs = 3.5 ml/kg/min of VO2) of physical activity performed was conducted using the automatic report provided from (http://www.ipaq.ki.se). The final report provided an estimation of the sum of MET per week.

2.5. Statistical analysis

Statistical analysis was performed using statistical package for social sciences (IBM SPSS) (version 27, Armonk, NY, USA). The normality of the variables was tested using the Kolmogorov-Smirnov test. Normally distributed variables were presented as mean and standard deviation, and non-normally distributed variables as median and interquartile range. Bivariate correlation using spearman's rank correlation coefficient analysis was used to assess the relationship between cardiorespiratory fitness, reported physical activity with sleep quality. Cross tabs were also used to investigate the frequency and contingency between the categorical data of reported physical activity (IPAQ) and sleep quality (PSQI). The level of significance was set at $p \leq 0.05$.

3. Results

The demographic characteristics of the participants are presented in Table 1. Some of the participants were smokers, but there was no difference in any demographic or the main outcome measures between the smokers and non-smokers (data not reported). The average sleep quality was poor, as indicated by the mean PSQI of the participants [19].

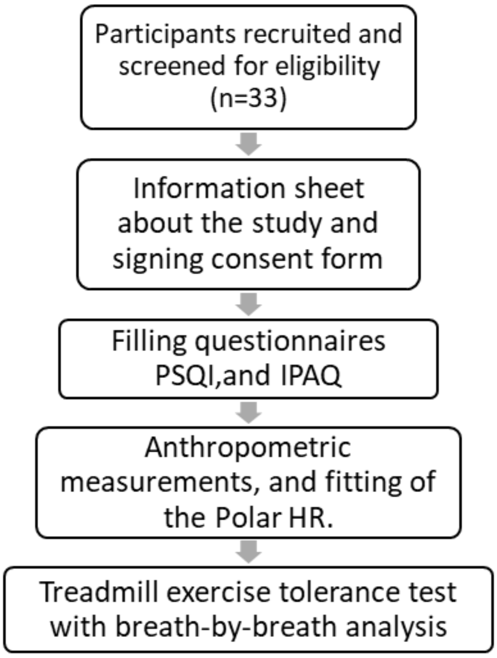

Figure 1. Flow diagram of the study protocol.

Table 1. Demographic characteristics of the participant

Characteristic	value
Age (years)	23 (22-24)
Weight (kg)	81.9 ± 17.9
Height (m)	1.72 ± 0.07
BMI (kg/m^2)	27.8 ± 8.7
- Normal BMI %	39.4%
- Overweight %	33.3%
- Obese %	27.3%
Smoker %	30.3
PSQI total score	7.3 ± 3.2
IPAQ (MET-min/week)	1215 (164-2335)
Resting HR (bpm)	77 (70-80)
Resting SBP (mmHg)	127 ± 9.9
Resting DBP (mmHg)	83 (63-83)
HR maximum (bpm)	169 ± 13.6
RER	1.15 ± 0.10
VO_2 peak (ml/kg/min)	28.4 ± 5.8

Values are presented as mean and standard deviation, or median (25th to 75th percentile) as appropriate. BMI; body mass index, PSQI; Pittsburgh sleep quality index, IPAQ; international physical activity questionnaire (short form), MET; metabolic equivalents. Normal BMI (18.5 – 24.9 kg/m2), overweight (25 – 29.9kg/m2), obese (30 kg/m2 and above), HR; heart rate, bpm; beat per minute; SBP; systolic blood pressure, DBP; diastolic blood pressure, RER; respiratory exchange ratio.

3.1. Correlation between VO2 peak and PSQI and its components

Correlational analysis was conducted to explore the association between VO2 peak and PSQI with all its components. There was no significant association between VO2 peak and the total score of the PSQI or any of the components of the sleep quality index (see table 2). As a sub-analysis, the correlation between IPAQ and PSQI total score was investigated. There was no significant association between IPAQ and PSQI (r (31) =-0.28, p=.11).

Table 2. Correlation analysis between VO2 peak and sleep quality index

Variable	VO_2 peak	
	r	*p*
Sleep quality	-0.21	.91
Sleep latency	0.50	.78
Sleep duration	0.60	.73
Sleep efficiency	-0.15	.40
Sleep disturbances	-0.29	.09
Sleep medication	0.54	.77
Sleep dysfunction	0.56	.76
PSQI total score	-0.07	.71

PSQI; Pittsburgh sleep quality index.

3.2. Cross-tabulation of the categorical data between IPAQ and PSQI

Cross tabs were used to investigate the frequency and the contingency between the categorical data of IPAQ and PSQI. IPAQ was categorized into three subgroups (low, moderate, high physical activity) based on the automatic report generated from the excel sheet (provided by the manufacturer). The frequency of good sleep quality and poor sleep quality based on the categorization of reported physical activity is demonstrated in Table 3. 84.8% of the participant had poor sleep quality (PSQI ≥ 5) of the total sample. Among participants with low PA (n=16), 93.8% of participants had poor sleep quality. 45.5% of the participants reported low physical activity and had poor sleep quality (see figure 2). The number of participants with poor sleep quality was decreasing with the higher categories of PA.

Table 3. Frequency distribution between IPAQ and PSQI

IPAQ category	PSQI category		Total
	Good sleep quality	Poor sleep quality	
Low PA n (%)	1 (6.3%)[a]	15 (93.8%)[b]	16 (48.5%)[c]
Moderate PA n (%)	3 (27.3%)[a]	8 (72.7%)[b]	11 (33.3%)[c]
High PA n (%)	1 (16.7%)[a]	5 (83.3%)[b]	6 (18.2%)[c]
Total	5 (15.2%)[a]	28 (84.8%)[b]	33

IPAQ; International physical activity questionnaire, PSQI; Pittsburgh sleep quality index, PA; physical activity. a; Indicate the percentage of participants with good sleep quality based on the IPAQ category's total number. b; Indicate the percentage of participants with poor sleep quality based on the IPAQ category's total number. c; indicate the percentage of participants in each category of IPAQ from the total sample.

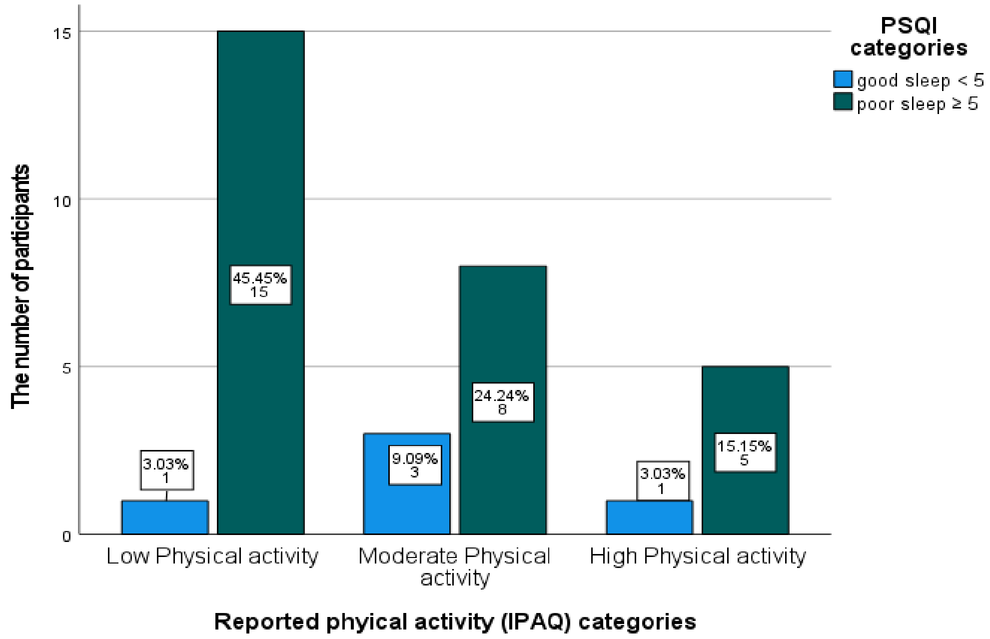

Figure 2. A Bar chart of the number and frequency between IPAQ categories and PSQI categories

4. Discussion

The current study explored the relationship between CRF (measured via VO2 peak), self-reported IPAQ (short form) with sleep quality index score (measured via PSQI). Contrary to our hypothesis, the study showed no significant relationship between CRF and PSQI and no significant relationship between IPAQ and PSQI. The study also showed that with increased reported physical activity on IPAQ, fewer participants had poor sleep scores on PSQI.

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Cardiopulmonary exercise testing is well-known as a gold standard for the measurement of CRF. CRF refers to the cardiopulmonary system's ability to transport oxygen from the atmosphere to the mitochondria to contribute to the performance of physical work. It also represents a quantification of the functional capacity which relies on the multiple systems to meet the metabolic demands exerted during physical work, and thus it is considered a reflection of total body health [21]. CRF can be measured directly or via estimation from the peak work achieved during physical work. Measurement of CRF via VO2 peak / VO2 max (e.g., breath analysis) is considered more objective and precise. In the current study, the use of direct measurement using breath-by-breath analysis was preferred. In this context, the study showed that the average VO2 peak of the participant was low, indicating reduced CRF, which is alarming, considering the participants' age ranges.

Limited studies were investigating the association between CRF and other parameters related to the quality of sleep. A longitudinal study reported no association between CRF and sleep disturbances in (n=88) females diagnosed with stress-related exhaustive disorders [12]. On the contrary, a cross-sectional study reported that poor CRF was weakly associated with poor sleep quality among (n=552) adolescents girls [9]. In the same context, a longitudinal epidemiological study found that a decline in CRF accelerates the risks of sleep problems, especially in middle-aged people [13]. The studies above utilized CRF estimation from peak physical work and different methodology was used to assess the association between CRF and sleep quality and different scales and outcome measures for sleep quality.

Few other studies utilized direct measurement of CRF and its association with sleep problems. A study consisted of apparently healthy men and women (n=3489) reported a moderate association between CRF (measured via VO2 peak) and sleep problems (known as insomnia) [8]. In analogous to our study's findings, a cross-sectional study reported no association between CRF and PSQI among (n=28) healthy males [22].On the contrary, a recent cross-sectional study in sedentary middle-aged people (n=74) reported better CRF (measured via VO2 max) was related to better PSQI scores[23]. The relationship between CRF and sleep quality (PSQI) existed when the participants were aged peopleas shown in the latter study [23]; however, when the studied population were younger as in the former study[22] and the current study, no relationship was found. Despite some differences in methodology, the former two studies by Antunes et al. [22] and Mochón-Benguiguiet al. [23], to some extent, were using similar outcome measures used in the current study but with different age categories. This may indicate that poor sleep quality's adverse outcomes, such as poor/reduced CRF, can be more evident among aged people and less prominent at a younger age. Indeed, age was considered one reason contributing to variation in the results reported in a systematic review about the interrelationship between sleep and exercise [11]. Furthermore, the relationship between CRF and sleep in both older and young adults was investigated. It was found that the relationship existed among aged people but was absent among young adults [24].

As a secondary aim to the current study, we sought to investigate the association between reported physical activity and sleep quality. Although no association was found between reported physical activity and PSQI, a high percentage of people with low PA also had poor sleep quality on PSQI (see Figure 2). This may indicate that people with less PA are more likely to have overall poor sleep quality. It was suggested that there is a bidirectional association between PA and sleep quality through physiological and psychological mechanisms [25]. These physiological mechanisms include the regular benefits of PA, such as improvement in vagal regulation of the heart, improve the endocrine system, whereas psychological mechanisms include improvement in mood, production of melatonin. These mechanisms contribute to better sleep which eventually contributes to better and more engagement into PA [25]. However, in terms of association, the absence of the association between PA and sleep quality was concluded by some studies when both PA and sleep quality were objectively measured[26], and when PA was objectively measured and sleep quality was subjectively reported [27].

The inverse association between reported PA (IPAQ) and sleep quality using PSQI has been reported in some studies. An inverse association was reported between the total duration of PA and PSQI total score among aged people [23] and young participants [28]. It is worth noting that in the current study, the energy cost of PA for the reported PA was utilized. However, in the previous studies, a different methodology was used. For example, one of the studies used the total IPAQ score in units of time [23], whereas the other study utilized categorization of activity as sufficient vs insufficient PA [28]. This made a direct comparison between the previous studies' results with the current one difficult due to different methodological approaches.

Almost half of the participants in the current study reported low PA. This was not surprising considering the average VO2 peak of the participants (see Table 1), indicating a lower CRF level. The prevalence of low PA in the current study is consistent with previous reports in the same country [29]–[31]. This is raising concerns about the future risk of comorbidities and cardiovascular diseases. Regarding the percentage of the participant with poor sleep, 85% experienced poor sleep, which is again consistent with previous studies [32]. This needs to be addressed in clinical practice and research by implementing more strategies to encourage further engagement to exercise and PA and more education about efficient sleep.

Despite the absence of association between CRF and sleep quality, the current study adds to the literature further knowledge about this association among young adult groups using CRF which was measured directly. This may warrant further research using more objective parameters for sleep quality, such as Actigrpah, accelerometers, which would give more robust data about the quantity and quality of sleep.

There are several limitations to the current study. Despite the good applicability and reproducibility of PSQI, it has some limitations as some of its components are weakly associated with the total score [33]. Thus, future research may consider the implementation of objective tools to assess sleep quantity and quality, which may offer better information and better representation of sleeping habits. This would also allow a better and more accurate detection of the relationship between CRF, especially when measured directly. Another limitation is the small sample and only males were included in the current study, limiting the generalizability of the results to the included participants only. Future research should be conducted on a larger sample with the inclusion of females. It must be noted that limitation in the number of participants happened due to the pandemic crisis, which made more recruitment of participants to be complicated.

5. Conclusions

In conclusion, the current study found no association between CRF and sleep quality or between reported PA and sleep quality. However, there was a high percentage of people who reported low PA and were also having poor sleep. Future cross-sectional studies should include objective measures for the quality and quantity of sleep and investigate the association with direct measurement of CRF.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, AO, BA; methodology, AO.; investigation, AO.; data curation, AO, SA, RK.; writing—original draft preparation, AO ; writing—review and editing, AO, RK, SA, WK.; visualization, AO, RK, WK, BA. All authors have read and agreed to the published version of the manuscript." Please turn

to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved the ethical committee of the deanship of scientific research at Prince Sattam bin Abdulaziz University, and all participants signed informed consent before participation. Written informed consent has been obtained from the participants to publish this paper.

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