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Original Article

Relationships between Musculoskeletal Disorders, Sleep Impairment, and Cardiorespiratory Fitness among Adolescents Aged 15-19 Years in Douala, Cameroon: A Cross-sectional Study

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Abstract

Background: Musculoskeletal disorders (MSDs) are a leading cause of disability worldwide. While poor sleep quality (PSQ) is considered an important risk factor for pain, high cardiorespiratory fitness (CRF) is a somewhat controversial protective factor. The present study investigated the association between MSDs, PSQ, and CRF in adolescents.
Methods: A cross-sectional, prospective study was conducted from November 2023 to March 2024 in Douala, Cameroon, among 15-to 19-year-old adolescents from public and private secondary schools. MSDs over the past three months (MSDs-3m) and the past week (MSDs-7d), as well as PSQ, were assessed using the Nordic and Pittsburgh sleep quality questionnaires, respectively. Then, CRF was estimated using the 20-meter shuttle run test. Quantitative analyses were performed using a t-test and qualitative by the chi-square test, respectively. Also, logistic regression was used to identify associations between MSDs, PSQ, and CRF, with statistical significance set at $P<0.05$.
Results: A total of 549 adolescents were included with a female predominance (64.5%). The respective prevalence rates for PSQ, MSDs-3m and MSDs-7d were 64.1%, 60.3% and 44.3%. MSDs were predominantly found in adolescents with PSQ (MSDs-3m: 52.8%, $P=0.007$; MSDs-7d: 64.5%, $P<0.001$). The neck (MSDs-3m=40.3%) and lower back (MSDs-7d=23.3%) were the body parts most affected in adolescents with PSQ. Neck pain was associated with MSDs ($P<0.01$) and an increase in all PSQ components, with sleep disturbances being mostly associated with MSDs in body regions ($P<0.01$). No association ($P>0.05$) was noticed between CRF and MSDs.
Conclusion: PSQ was a significant risk factor for MSDs in adolescents, whilst CRF did not protect against MSDs.

Keywords: Musculoskeletal Disorders, Quality of Sleep, Cardiorespiratory Fitness, Adolescents, Cameroon

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1. Introduction

Adolescence constitutes an important period of transition from childhood to adulthood on physical, psychological, and social aspects according to Jaworska and MacQueen (1). During this period, the regular practice of physical activity is imperatively associated with good mental and physical health (1), and good health in adulthood (2). However, pain is one of the main problems causing disabilities and limitations in physical activity among adolescents (3). Pain, particularly joint pain, can negatively affect physical activity, resulting in severe limitations in mobility, dexterity, health, and quality of life (4, 5). These pains are primarily localized in the musculoskeletal system (joints, tendons, muscles, ligaments, nerves and structures that support the limbs, back, and neck) and are known as musculoskeletal disorders (MSDs).

MSDs are prevalent among adolescents and are a major concern regarding disability worldwide (6). More than a quarter of children and adolescents (40%) suffer from MSDs (7), which can become persistent and impact quality of life, as well as

increasing the use of healthcare and analgesic drugs (8). MSDs in adolescents resemble those observed in adults (4). Additionally, in a fraction of adults, MSDs may have originated from childhood and adolescence, thereby highlighting the need to understand risk factors within childhood and adolescence (9). MSDs origins are complex and multifactorial, involving an interplay between psychosocial context, biomechanical stress, individual-related environment, genetic factors, and behavioral factors. In adolescents and children, sleep problems constitute one potential determinants of MSDs (10).

Furthermore, there is an interplay between pain and sleep impairments. Pain can impair the quality and quantity of sleep, and poor sleep can increase pain (11). Sleep is an important physiological process that contributes to psychological, physical, and emotional well-being. It has key roles not only in the physical development of adolescents, but also in behavior, emotion, cognition, attention, and school performance. Good sleep is related to energy repair, protection and recovery, and is an essential factor for maintaining the well-being of overall health and homeostasis (11). During adolescence, sleep disturbances are associated with cognitive impairment, as well as with immunological, inflammatory, and cardiometabolic diseases (12). Notably, electronic devices and screens have become an integral part of adolescents' daily lives, particularly for study, entertainment, and communication, regardless of the time of day. It is well known that excessive use of new technologies at night deteriorates sleep quality and is one of the leading causes of poor sleep quality (PSQ) (13).

Cardiorespiratory fitness (CRF) is generally related to health (14). High cardiorespiratory levels and muscular fitness have been associated with a significant reduction in disease risk, positive health and better health related to quality of life in adolescents (15). The implementation of physical exercise interventions in childhood and adolescence have been generally considered as a preventive tool against both MSDs (6) and PSQ (16). Aerobic physical activity exert a positive impact on musculoskeletal health by reducing pain (17) in adolescents and improving good sleep (18). Therefore, the present study primarily aimed to determine the prevalence of MSD besides its association with PQS among adolescents. Also, we aimed to determine the preventive effect of CRF on the occurrence of MSD.

2. Methods

2.1. Design

This cross-sectional, prospective, analytical study was conducted from November 2023 to March 2024 in Douala, Cameroon.

2.2. Selection and Description of Participants

The study participants were recruited from three private and public secondary schools. Adolescents aged 15-19 were interviewed by researchers who collected data using pre-tested and structured questionnaires. Healthy adolescents with no history of joint trauma or undergoing drug treatment prescribed to relieve pain or aid sleep were included in this study. Those convalescing, unable to participate in physical activities or sports, or undergoing drug treatment were excluded from the study.

2.3. Sample Size Determination

The minimum of the sample size was determined using the Lorentz's formula ($N=p(1-p)z^2/d^2$), where N is the minimum sample size, p is the prevalence, z is 1.96 for a 95% confidence level, and d is 0.05. With a reported prevalence of 67.5% of the association between poor sleep and musculoskeletal disorders (MSD) among Brazilian adolescents by Batista and colleagues (19), the minimum sample size was 337 participants.

2.3.1. Data Collection and Measurements

2.3.1.1. Socio-demographic Information and Anthropometric Measures

Personal sociodemographic information of adolescents, such as gender, age, trauma antecedents, and smartphone possession and usage, was collected using an elaborated structured questionnaire. An electronic scale (Tanita BC-532, Tokyo, Japan) was used to measure weight. Height was measured with a graduated rod to the nearest centimeter. Body mass index (BMI) was determined using Quetelet's formula: BMI (kg/m^2)=weight (kg)/height^2 (m^2). BMI values were interpreted using the classification of the international Obesity Task Force to determine weight status (20).

2.3.1.2. Content Validity

To assess the qualitative content validity of the questionnaires, 120 adolescents (40 from each grade level of secondary school) were invited to provide detailed feedback on the questionnaires, including their perceptions of the wording, grammar, simplicity, and clarity of the items. They also commented on the importance and feasibility of the questionnaires. The research team then made amendments to the items. Content validity index (CVI) and content validity ratio (CVR) were evaluated for the questionnaire assessing quality, quantity of sleep, and MSDs in the quantitative content validity assessment.

2.3.1.3. Quality of Sleep

Poor quality of sleep is determined using a French version of the Pittsburgh Sleep Quality Index (PSQI) questionnaire (21). This valid and reliable instrument assesses an individual's sleep quality over the course of a month. The 19-item PSQI questionnaire analyzes sleep quality in seven components: sleep latency, efficiency, duration, medication use, daytime dysfunction, and disturbances. Each PSQI component is scored between 0-3, and the sum of PSQI components yields a global sleep quality score ranging from 0-21 points. A total score of PSQI >6 is considered as PSQ.

A CVI of 0.96 and a CVR of 0.91 were obtained for the entire questionnaire, indicating favorable validity.

2.3.1.4. Musculoskeletal Disorders

The Nordic questionnaire in French version adapted to adolescents population was used to assess rate of MSDs (22). This structured and validated questionnaire assesses the occurrence of MSDs during the last three months, and the week on nine body areas joints (shoulders, neck, wrists/hands, elbows, hips/thighs, lower back, upper back, ankles/feet, and knees). In the present study, we assessed MSDs during the last seven days (MSDs-7d) and the last three months (MSDs-3m). For each above-mentioned region, the parameters evaluated were:

- Absence or presence of pain, aches or stiffness in the last three months or last week

- Absence from physical education teaching sessions during the last three months or last seven related to pain in one or more body sites

- Trauma antecedents in one or more body sites in the last three months or last seven days

A CVI of 0.97 and a CVR of 0.99 were obtained for the entire questionnaire, indicating favourable validity.

2.4. Cardiorespiratory Fitness

Cardiorespiratory fitness (CRF) is estimated by the 20-m shuttle run test (20-SRT), which estimates maximal oxygen uptake (VO_2max) estimating maximal oxygen uptake. 20-SRT consists in running between two parallels lines of 20-meter track limited by visual landmarks with an initial speed of 8.5 $Km.h^{-1}$ and an increment of 0.5 every 2 minutes. The test ended when adolescents could no longer follow the beeping sound. Thereafter, VO_2max was estimated with the formula of Léger and co-workers (23) for adolescents aged >18 years, and the formula of Barnett and colleagues (24) for those aged <18 years.

2.5. Procedure

Ethical approval for the study was granted by the institutional Ethics Committee of the University of Douala in accordance with the 1989 revised recommendations of the Declaration of Helsinki. A trained research assistant approached eligible participants and explained the aim and procedures of the study. The participants were then asked to complete the study questionnaire, which took an average of 10–15 minutes. The research assistant was available to answer any questions. Since each participant was anonymized through codification for statistical analysis, it was impossible to share the data directly with each participant. Convalescent adolescents were excluded from the study.

2.6. Data Analysis

The data were entered into Microsoft Excel 2016 software. Statistical analysis was performed using SPSS version 20.0 (SAS Institute, Inc., Chicago, Illinois, USA). Data normality was verified with the non-parametric Kolmogorov-Smirnov test. In the quantitative stage of the analysis, mean and standard deviation values were calculated, while percentages were computed to summarize qualitative variables.

For the comparison of quantitative variables, an independent t-test was used to of unpaired variables. Additionally, Pearson's chi-^{2} test was conducted to compare unpaired qualitative variables. Logistic regression models were realized to identify factors associated with MSDs and PSQ. We performed a univariate logistic regression by stratifying the results related to the risk of MSDs of each body region, as per gender, PQSI index, sleep latency, subjectivity, duration, sleep quality, efficiency, daytime dysfunction, disturbances, medication, and V_{O2}max (25). The choice of the sleep-related variables relied on the above-mentioned aim of the present work to evaluate the impact of sleep quality on risk of MSDs. Also, variables such as age, gender, and VO_2max were included in the analysis, given that some studies (26-28) reported associations with MSD risk. Then, associations were quantified by computing crude odds ratios adjusted for age and gender at a 95% confidence interval (95% CI). The statistical significance threshold was set at P<0.05.

3. Results

A total of 817 adolescent pupils were recruited. Then, 268 were excluded due to incomplete questionnaires and inability to perform the 20-m shuttle run test to assess the maximal oxygen uptake.

As Table 1 depicts the baseline characteristics of the participants, a total of 549 adolescents were finally included in the study of whom female individuals accounted for 64.5%. More than half were aged under 18 years (73%) with a higher proportion of participants being female (49.4%; P=0.01). The majority (65.6%) of adolescents were using an Android phone. In addition, the proportion of Android phone users was higher in female individuals than male ones (37.9% Vs 7.8%, P<0.001). Based on ponderal status, the majority had a normal BMI (88.6%). Also, mean BMI was significantly higher in female adolescents (P<0.001). Age, height, weight and maximal oxygen update were significantly greater in boys (P<0.01).

The overall prevalence of PSQ was 64.1%, with female individuals being overrepresented (67.9%; P=0.02). PQS indexes, sleep disturbances, sleep onset latency and daytime dysfunction increased

Table 1: General characteristics of the population

Variables	Categories	Total	Boys	Girls	P value
Type of School	Private	81 (14.8)	30(5.5)	51(9.3)	0.09
	Public	468 (85.2)	165(30.0)	303(55.2)	
Age (years)	<18	401 (73)	130(23.7)	271(49.4)	0.01*
	≥18	148 (27)	65(11.8)	83(15.1)	
Ponderal Status	Underweight	12 (2.4)	8(1.5)	4(0.7)	<0.001*
	Normal	449 (88.6)	161(29.3)	330(60.1)	
	Overweight	29 (5.7)	0(0.0)	29(5.3)	
	Obese	17 (3.4)	0(0.0)	17(3.1)	
Use of Android Phone	No	189 (34.4)	146(26.6)	146(26.6)	<0.001*
	Yes	360 (65.6)	43(7.8)	208(37.9)	
	Poor Sleep	352(64.1%)	113(32.1%)	239(67.9%)	0.02
Age (Years)		17±1	17±2	16±1	0.001*
Height (m)		1.66±0.08	1.72±0.07	1.62±0.06	<0.001*
Weight (Kg)		59.8±9.7	61.5±8.1	58.9±10.3	0.004*
BMI (Kg.m^{-2})		21.9±3.5	20.7±2.2	22.4±3.9	<0.001*
$V0_2$max (ml/kg/min)		42.5±5.9	40.7±5.3	46.2±5.3	<0.001*
PSQI Index		6.8±2.9	6.4±2.9	7.0±2.9	0.01*
Sleep Subjectivity		1.2±0.8	1.1±0.7	1.2±0.9	0.21
Sleep Onset Latency		1±0.9	0.8±0.9	1.0±0.9	0.03*
Sleep Duration		1.1±0.9	1.2±0.8	1.1±0.9	0.07
Sleep Efficiency		0.4±0.7	0.4±0.8	0.4±0.7	0.66
Sleep Quality		1.2±0.8	1.1±0.7	1.2±0.9	0.21
Disturbances		1.4±0.6	1.2±0.6	1.4±0.5	<0.001*
Medication		0.5±0.9	0.4±0.7	0.5±0.9	0.35
Daytime Dysfunction		1.3±1	1.1±0.9	1.4±1	0.001*

Values are either n (%) or Mean±SD; n: number of participants; PSQI: Pittsburg Sleep Quality Inventory; BMI: Body Mass Index; VO_2max: Maximal Oxygen Uptake

significantly in girls (P<0.05) (Table 1). As shown in Figure 1, the prevalence of MSDs was 60.3% and 44.3% during the last three months and the last seven days, respectively. MSDs were more prevalent among adolescents with PSQ (MSDs-3m: 52.8% vs. 34%; MSDs-7d: 64.5% vs. 50%; P=0.007 and P<0.001, respectively). No difference (P>0.05) in PSQ prevalence was noted between girls and boys. MSDs were more prevalent in adolescents with fewer than three affected body regions during the last three months (77.9%) and one week (73.3%). According to sleep quality and the number of body regions affected, MSD prevalence was significantly higher in adolescents with PSQ (MSDs-3m <3: 51.1% vs. 26.9%, P=0.02; MSDs-3m ≥3: 17.5% vs. 4.5%, P=0.02).

MSDs affecting the neck were more prevalent in adolescents with PSQ (40.3% vs. 26.4%, P=0.001) than in those with good sleep quality. Among adolescents with PSQ, MSDs-3m were most frequently reported in the neck (40.3%), followed by the shoulders (19.3%). The prevalence of MSDs-7d was higher on lower back (23.3%) and neck (16.8%) regions (Table 2). During the week, the prevalence of MSDs-7d was significantly higher in adolescents with PSQ than in those with good sleep quality for the following body regions: neck (16.8% vs. 6.6%, P<0.001), upper back (8.2% vs. 3.6%, P=0.03), lower back (23.3% vs. 13.7%, P=0.006) and hips/thighs (14.5% vs. 8.1%, P=0.02).

The logistic regression analysis established an association between overall MSDs and PQS are summarized in Table 3. There was a significant association between MSDs-3m, MSDs-7d and sleep components. Indeed, an increase of one unit in PSQI was linked with a 1.12-fold increase in the likelihood of experiencing MSDs-3m (aOR: 1.12, 95% CI: 1.05–1.19, P<0.001) and a 1.18-fold increase in the likelihood of experiencing MSDs-7d (aOR: 1.18, 95% CI: 1.11–1.26, P<0.001). Similarly, an increase of one unit in sleep subjectivity (aOR: 1.37, 95% CI: 1.07–1.75, P=0.01), sleep onset latency (aOR: 1.24, 95% CI: 1.02–1.51, P=0.03), sleep quality (aOR: 1.37, 95% CI: 1.07–1.75, P=0.01), disturbances (aOR: 1.98, 95% CI: 1.44–2.73, P<0.001) and daytime dysfunction (aOR: 1.41, 95% CI: 1.17–1.68, P<0.001) was linked with increased odds of MSDs-3m. Conversely, the likelihood of MSDs-3m decreased by 23% (aOR=0.77, 95% CI 0.61–0.98, P=0.03) with each one-unit decrease in the sleep efficiency score. The same patterns were observed between MSDs-7d and increased sleep subjectivity (aOR: 1.78, 95% CI: 1.38–2.28, P<0.001), increased

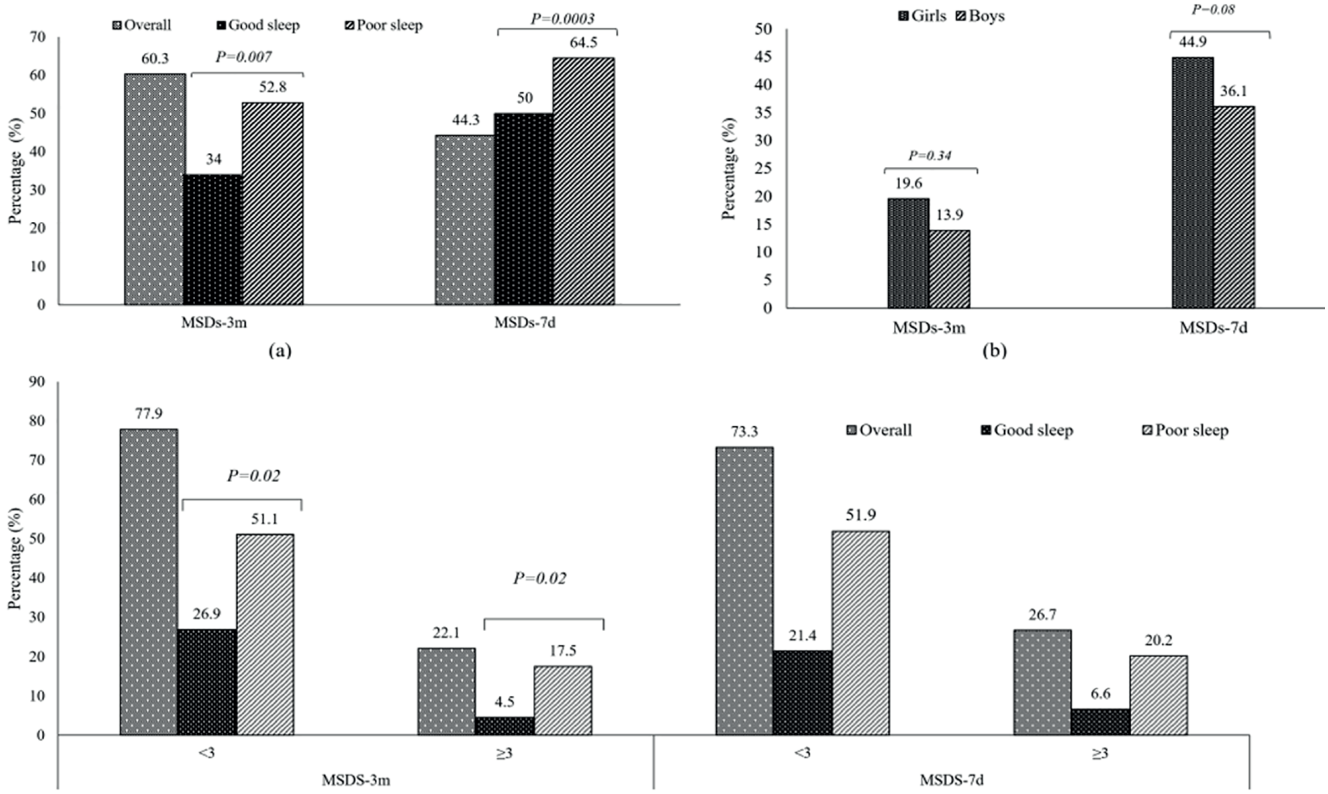

Figure 1: The figure shows the Musculoskeletal Disorders in the population according to quality of sleep, (a) gender (b) and number of affected regions and quality of sleep (c). MSDs-3m: Musculoskeletal disorders during the last 3 months; MSDs-7d: Musculoskeletal disorders during the seven last days

Table 2: Body regions affected by Musculoskeletal Disorders according to quality of sleep

Body regions	MSDs-3m(+)		P value	MSDs-7d (+)		P value
	Good Sleep n (%)	Poor Sleep n (%)		Good Sleep n (%)	Poor Sleep n (%)	
Neck	52(26.4)	142(40.3)	0.001*	13(6.6)	59(16.8)	<0.001*
Shoulders	30(15.2)	68(19.3)	0.23	16(8.1)	37(10.5)	0.35
Elbows	7(3.6)	13(3.7)	0.93	4(2.0)	9(2.6)	0.69
Wrists/Hands	6(3.1)	19(5.4)	0.20	14(7.1)	19(5.4)	0.41
Upper Back	21(10.7)	40(11.4)	0.80	7(3.6)	29(8.2)	0.03*
Lower Back	21(10.7)	56(15.9)	0.08	27(13.7)	82(23.3)	0.006*
Hips/Thighs	13(6.6)	37(10.5)	0.20	16(8.1)	51(14.5)	0.02*
Knees	9(4.6)	31(8.8)	0.06	12(6.1)	35(14.5)	0.12
Ankles/Feet	6(3.1)	24(6.8)	0.06	12(6.1)	33(9.9)	0.17

MSDs-3m: Musculoskeletal Disorders during the last 3 months; MSDs-7d: Musculoskeletal Disorders during the seven last days

Table 3: Association between Musculoskeletal Disorders and quality of sleep

Variables	MSDs-3m(+)		MSDs-7d (+)	
	aOR (95%CI)	P value	aOR (95%CI)	P value
Age	0.87(-078-0.97)	0.01*	1.02(0.92-1.14)	0.71
Gender				
Female	1		1	
Male	0.61(0.43-0.88)	0.007*	0.62(0.43-0.89)	0.009*
PSQI Index	1.12(1.05-1.19)	<0.001*	1.18(1.11-1.26)	<0.001*
Sleep Subjectivity	1.37(1.07-1.75)	0.01*	1.78(1.38-2.28)	<0.001*
Sleep Onset Latency	1.24(1.02-1.51)	0.03*	1.41(1.16-1.70)	<0.001*
Sleep Duration	1.09(0.89-1.33)	0.42	1.15(0.94-1.40)	0.16
Sleep Efficiency	0.77(0.61-0.98)	0.03*	0.86(0.68-1.10)	0.22
Sleep Quality	1.37(1.07-1.75)	0.01*	1.78(1.38-2.28)	<0.001*
Disturbances	1.98(1.44-2.73)	<0.001*	1.77(1.30-2.39)	<0.001*
Medication	1.10(9.90-1.36)	0.35	1.29(1.05-1.57)	0.01*
Daytime Dysfunction	1.41(1.17-1.68)	<0.001*	1.39(1.16-1.65)	<0.001*
V0$_2$max (mL/kg/min)	1.02(0.98-1.05)	0.36	1.01(0.96-1.04)	0.81

MSDs-3m: Musculoskeletal Disorders during the last 3 months; MSDs-7d: Musculoskeletal Disorders during the seven last days; aOR: Adjusted Odd Ratio; CI: Confidence Interval; PSQI: Pittsburg Sleep Quality Inventory; VO_2max: Maximal Oxygen Uptake

sleep onset latency (aOR: 1.41, 95% CI: 1.16–1.70, P<0.001), increased sleep quality (aOR: 1.78, 95% CI: 1.38–2.28, P<0.001), increased disturbances (aOR: 1.77, 95% CI: 1.30–2.39, P<0.001) and increased medication use (aOR: 1.29, 95% CI: 1.05–1.57, P=0.01), and daytime dysfunction (aOR: 1.39, 95% CI 1.16–1.65, P<0.001). No significant association (P>0.05) was observed between sleep components and maximal oxygen uptake.

Table 4 summarizes the association between sleep components and musculoskeletal disorders (MSDs) in different body regions. During the last 3 months, the risk of MSDs in the neck region was significantly associated with six sleep components (sleep latency, subjectivity, quality, duration, daytime dysfunction and disturbances). During the last 7 days, the risk of MSDs in the neck region was significantly associated with five PSQI components (subjectivity, sleep latency, quality, disturbances, daytime dysfunction and medication). Of the PSQI components, sleep disturbances were most strongly associated with the following body regions: shoulders, neck, lower back, knees, and hips/thighs.

An increase of one unit in the PSQI score was significantly associated with an increased risk of MSDs-3m in the neck (aOR: 1.15, 95% CI: 1.08–1.23, P<0.001), shoulders (OR: 1.15, 95% CI: 1.07–1.24, P<0.001), lower back (aOR: 1.10, 95% CI: 1.01–1.19, P=0.02), hips/thighs (aOR: 1.19, 95% CI: 1.08–1.30, P<0.001) and ankles/feet (aOR: 1.17, 95% CI: 1.04–1.32, P=0.008). The risk of MSDs on the neck increased by 15% for every one-unit increase in PSQI (aOR=1.15, P<0.001), and by 40% for every one-unit increase in sleep subjectivity (aOR=1.40, P=0.005). Other factors associated with an increased risk of MSDs on the neck were sleep onset latency (aOR=1.24, P=0.03), sleep duration (aOR=1.27, P=0.02), sleep disturbances

Table 4: Association of Musculoskeletal Disorders with quality of sleep and aerobic aptitude during the last 3 months

		Neck	Shoulders	Wrists/Hands	Lower Back	Hips/Thighs	Knees	Ankles/feet
		aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)
Age		0.93(0.83-1.65)	0.78(0.66-0.92)	0.90(0.68-1.19)	1.10(0.95-1.27)	1.09(0.91-1.30)	0.96(0.77-0.18)	0.87(0.66-1.13)
Gender	Female	1	1	1	1	1	1	1
	Male	0.67(0.46-0.93) *	0.70(0.43-1.14)	1.07(0.46-2.48)	0.82(0.49-1.37)	0.99(0.53-1.29)	1.25(0.65-2.44)	0.57(0.24-1.35)
PSQI Index		1.15(1.08-1.23) *	1.15(1.07-1.24) *	1.12(0.99-1.28)	1.10(1.01-1.19) *	1.19(1.08-1.30) *	1.08(0.97-1.30)	1.17(1.04-1.32) *
Sleep Subjectivity		1.40(1.11-1.78) *	1.54(1.15-2.05) *	0.90(0.52-1.54)	1.39(1.06-1.84) *	1.76(1.23-2.52) *	1.23(0.91-1.67)	1.29(0.94-1.77)
Sleep Onset Latency		1.24(1.02-1.50) *	1.24(0.98-1.58)	1.13(0.81-1.91)	1.16(0.89-1.50)	1.22(0.90-1.67)	1.12(0.79-1.58)	1.40(0.95-2.05)
Sleep Duration		1.27(1.03-1.55) *	1.11(0.86-1.43)	1.65(1.06-2.56) *	1.14(0.86-1.50)	0.95(0.67-1.33)	0.81(0.55-1.20)	1.07(0.70-1.63)
Sleep Efficiency		0.97(0.76-1.24)	1.0(0.74-1.36)	1.20(0.73-1.96)	1.06(0.77-1.47)	0.83(0.53-1.31)	0.60(0.32-1.13)	0.53(0.24-1.18)
Sleep Quality		1.40(1.11-1.78) *	1.54(1.15-2.05) *	0.90(0.52-1.54)	1.39(1.06-1.84) *	1.76(1.23-2.52) *	1.23(0.91-1.67)	1.29(0.94-1.77)
Disturbances		1.91(1.39-2.61) *	2.02(1.37-2.96) *	1.31(0.66-2.59)	1.58(1.04-2.40) *	2.07(1.26-3.42) *	1.75(1.02-3.01) *	1.67(0.87-3.14)
Medication		1.14(0.93-1.39)	1.17(0.92-1.48)	1.31(0.88-1.96)	0.94(0.71-1.26)	1.23(0.91-1.66)	1.36(0.98-1.87)	1.59(1.14-2.22) *
Daytime Dysfunction		1.39(1.15-1.66) *	1.35(1.08-1.70) *	1.08(0.72-1.62)	1.17(0.92-1.49)	1.86(1.35-2.55) *	1.31(0.94-1.81)	1.58(1.07-2.32) *
$V0_2$max (mL/kg/min)		1.03(0.99-1.07)	0.98(0.94-1.03)	0.99(0.91-1.08)	0.99(0.95-1.05)	1.03(0.97-1.10)	1.0(0.93-1.07)	1.01(0.93-1.08)

*=P<0.05: significant difference; MSDs-3m: Musculoskeletal Disorders during the last 3 months; AOR: Adjusted Odd Ratio; CI: Confidence Interval; PSQI: Pittsburg Sleep Quality Inventory; VO_2max: Maximal Oxygen Uptake

(aOR=1.91, P<0.001) and daytime dysfunction (aOR=1.39, P<0.001). The same risk was observed for subjective sleepiness in the neck (OR: 1.40, 95% CI: 1.11–1.78, P=0.005), shoulders (aOR: 1.54, 95% CI: 1.15–2.05, P<0.001), lower back (aOR: 1.39, 95% CI: 1.06–1.84, P=0.01) and hips/thighs (aOR: 1.76, 95% CI: 1.23–2.52, P=0.002). The same risk was also observed for sleep onset latency in the neck (aOR: 1.24, 95% CI: 1.02–1.50, P=0.03) and sleep duration in the neck (OR: 1.27, 95% CI 1.03–1.55, P=0.02) and wrists/hands (aOR: 1.65, 95% CI 1.06–2.56, P=0.02). Poor sleep quality was associated with pain in the neck (aOR: 1.40, 95% CI: 1.11–1.78, P=0.005), shoulders (aOR: 2.02, 95% CI: 1.37–2.96, P<0.001), lower back (aOR: 1.58, 95% CI: 1.04–2.40, P=0.03) and hips/thighs (aOR: 2.07, 95% CI: 1.26–3.42, P=0.004). Disturbances were significantly associated with the neck (OR: 1.91, 95% CI: 1.39–2.61, P<0.001), shoulders (aOR: 2.02, 95% CI: 1.37–2.96, P<0.001), lower back (aOR: 1.58, 95% CI: 1.04–2.40, P=0.03), hips/thighs (aOR: 2.07, 95% CI: 1.26–3.42, P<0.001) and knees (aOR: 1.75, 95% CI: 1.02–3.01, P=0.04). The use of medication was significantly associated with an increased risk of MSDs in the ankles/feet (aOR: 1.59, 95% CI: 1.14–2.22, P=0.006), daytime dysfunction in the neck (OR: 1.39, 95% CI: 1.15–1.66, P<0.001), shoulders (aOR: 1.35, 95% CI: 1.08–1.70, P=0.009), hips/thighs (aOR: 1.86, 95% CI: 1.35–2.55, P<0.001) and ankles/feet (aOR: 1.58, 95% CI: 1.07–2.32, P=0.02).

As presented in Table 5, the risk of MSDs-7d in the neck increased by 15% for every increase of the PSQI index (aOR: 1.15, 95%CI: 1.08–1.23, P<0.001). The risk also increased with sleep subjectivity (aOR: 1.63, 95% CI: 1.19–1.19, P=0.002), sleep onset latency (aOR: 1.31, 95% CI: 1.01–1.71, P=0.04), sleep quality (aOR: 1.63, 95% CI: 1.19–2.23, P=0.002) and sleep disturbances (aOR: 2.01, 95% CI: 1.31–3.10, P=0.001), medication (aOR=1.31, 95% CI: 1.02–1.69, P=0.03) and daytime dysfunction (aOR=1.85, 95% CI: 1.41–2.42, P<0.001).

The risk of MSDs-7d was observed in the shoulders, with the following factors being significant predictors: PSQI (aOR: 1.19, 95% CI: 1.09–1.31, P<0.001); sleep subjectivity (aOR: 1.83, 95% CI: 1.27–2.64, P=0.001); sleep onset latency (aOR: 1.46, 95% CI: 1.08–1.97, P=0.01); sleep quality (aOR: 1.83, 95% CI: 1.27–2.64, P=0.001); sleep disturbances (aOR: 1.89, 95% CI: 1.15–3.09,

Table 5: Association of Musculoskeletal Disorders with quality of sleep and aerobic aptitude during the last 7 days

		Neck	Shoulders	Upper Back	Lower Back	Hips/Thighs	Knees
		aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)
Age		1.01(0.86-1.18)	0.92(0.76-1.13)	1.05(0.85-1.29)	1.08(0.94-1.23)	0.88(0.73-1.05)	1.09(0.91-1.30)
Gender	Female	1	1	1	1	1	1
	Male	0.72(0.41-1.23)	0.52(0.26-1.01)	0.88(0.43-1.81)	0.61(0.38-0.98)*	0.79(0.45-1.38)	1.33(0.72-2.46)
PSQI Index		1.19(1.10-1.30)*	1.19(1.09-1.31)*	1.24(1.11-1.38)*	1.15(1.07-1.24)*	1.18(1.09-1.29)*	1.14(1.03-1.26)*
Sleep Subjectivity		1.63(1.19-1.19)*	1.83(1.27-2.64)*	1.49(1.07-2.08)*	1.74(1.34-2.31)*	1.80(1.28-2.51)*	1.42 (1.05-1.91)*
Sleep Onset Latency		1.31(1.01-1.71)*	1.46(1.08-1.97)*	1.47 (1.03-2.08)*	1.20(0.96-1.51)	1.33(1.01-1.75)*	1.15(0.84-1.59)
Sleep Duration		0.91(0.68-1.22)	1.06(0.77- 1.48)	1.13(0.77-1.66)	1.27(1.01-1.62)*	1.29(0.97-1.73)	0.79(0.55-1.15)
Sleep Efficiency		0.94(0.66-1.34)	0.89(0.58-1.35)	1.25(0.83-1.88)	1.05(0.79-1.40)	1.03(0.72-1.45)	1.05 (0.70-1.58)
Sleep Quality		1.63(1.19-2.23)*	1.83 (1.27-2.64)*	1.49(1.07-2.07)*	1.74(1.30-2.31)*	1.80(1.28-2.51)*	1.42 (1.05-1.91)*
Disturbances		2.01(1.31-3.10)*	1.89 (1.15-3.09)*	1.70(0.95-3.03)	1.54(1.07-2.23)*	1.91(1.23-2.96)*	2.09 (1.26-3.49)*
Medication		1.31(1.02-1.69)*	1.30 (0.98-1.73)	1.28(0.91-1.80)	1.08(0.85-1.36)	1.16(0.88-1.53)	1.39(1.04-1.88)*
Daytime Dysfunction		1.85(1.41-2.42)*	1.85(1.41-2.42)*	2.0(1.38-2.92)*	1.31 (1.05-1.62)*	1.27(0.97-1.65)	1.37(1.01-1.87)*
$V0_2$max (mL/kg/min)		0.97(0.92-1.02)	1.01(0.96-1.07)	0.94(0.87-1.01)	1.02(0.97-1.06)	1.04(0.99-1.10)	0.99(0.92-1.06)

*=P<0.05: Significant difference; MSDs-7d: Musculoskeletal Disorders during the seven last days; aOR: Adjusted Odd Ratio; CI: Confidence Interval; PSQI: Pittsburg Sleep Quality Inventory; VO_2max: Maximal Oxygen Uptake

P=0.01); and daytime dysfunction (aOR=1.85, 95% CI: 1.41–2.42, P<0.001), increasing with each one-unit increase. This increase was also associated with MSDs-7d in the upper back (aOR: 1.24, 95% CI: 1.11–1.38, P<0.001), sleep subjectivity (aOR: 1.49, 95% CI: 1.07–2.08, P=0.01), sleep onset latency (aOR: 1.47, 95% CI: 1.03–2.08, P=0.03), sleep quality (aOR: 1.49, 95% CI: 1.07–2.07, P=0.01) and daytime dysfunction (aOR: 2.00, 95% CI: 1.38–2.92, P<0.001). The same patterns were reported for the lower back in relation to the PSQI (aOR: 1.15, 95% CI: 1.07–1.24, P<0.001), sleep subjectivity (aOR: 1.74, 95% CI: 1.34–2.31, P<0.001), sleep duration (aOR: 1.27, 95% CI: 1.01–1.62, P=0.04), sleep quality (aOR: 1.74, 95% CI: 1.30–2.31, P<0.001), sleep disturbance (aOR: 1.54, 95% CI: 1.07–2.23, P=0.02) and daytime dysfunction (aOR: 1.31, 95% CI: 1.05–1.62, P=0.01). MSDs-7d on hips/thighs were also associated with PSQI (aOR: 1.18, 95% CI: 1.09–1.29, P<0.001), sleep subjectivity (aOR: 1.80, 95% CI: 1.28–2.51, P<0.001), sleep onset latency (aOR: 1.33, 95% CI: 1.01–1.75, P=0.03), sleep quality (aOR: 1.80, 95% CI: 1.28–2.51, P<0.001) and sleep disturbance (aOR: 1.91, 95% CI: 1.23–2.96, P=0.004). Similarly, MSDs-7d in the knees were associated with PSQI (aOR: 1.14, 95% CI: 1.03–1.26, P=0.008), sleep subjectivity (aOR: 1.42, 95% CI: 1.05–1.91, P=0.02), sleep quality (aOR: 1.42, 95% CI: 1.05–1.91, P=0.02), sleep disturbance (aOR: 2.09, 95% CI: 1.26–3.49, P=0.004), sleep medication (aOR: 1.39, 95% CI: 1.04–1.88, P=0.02) and daytime dysfunction (aOR: 1.37, 95% CI: 1.01–1.87, P=0.04).

4. Discussion

This study focused on the relationship between MSDs, poor sleep quality, and the protective effects of cardiorespiratory fitness against MSDs in adolescents. The results revealed that MSDs are more prevalent among adolescents and are significantly linked with PSQ and sleep components of the PSQI. Additionally, CRF did not exert a preventive effect against joint pain.

It was noticed that according to gender MSDs were higher in adolescents with PSQI. This result was consistent with previous research studies which highlighted the potential effects of sleep disorders on musculoskeletal pain, and found that MSDs were more prevalent in adolescents and children with impaired sleep (10, 19, 29). A longitudinal study of 3 years, conducted among adolescents aged 16 in Suede, reported a link between poor quality of sleep and MSDs (30). However, our findings did not support those of a study conducted by Andreucci and colleagues (31), who argued that a link between poor sleep and MSDs might be related to the heterogeneity of the study populations and sex differences.

The present research study found no gender-based differences in sleep problems or musculoskeletal disorders (MSDs), which was consistent with our previous work in the same city (32). However, Andreucci and colleagues (29) found that boys suffering from sleep disturbances were at a greater risk of developing MSDs, whereas girls were not. According to body region, MSDs-3m were most frequently reported in the neck (40.3%) and shoulders (19.3%), while MSDs-7d were most frequently reported in the lower back (23.3%) and

neck (16.8%). This differed from an observational study of Batista and colleagues (19) in adolescents, which found that the regions most affected by musculoskeletal pain and poor sleep quality over the previous 12 months were the upper back, lower back, and knees.

Logistic regression outlined increased risk of MSDs on neck, lower back, shoulders, hips/thighs and knees with impairment in sleep components. This was consistent with previous research studies that pointed out an increased risk of MSDs in the neck, shoulders, and lower back in adolescents with sleep problems (31, 33). It should be noted that, based on the literature search, the present study is the first to granularly analyze the association between sleep quality and MSDs using sophisticated statistical analyses such as logistic regressions. These analyses allowed us to conclude that increase in PSQI, or its components (i.e., sleep disturbances, sleep subjectivity, daytime dysfunction, and quality), are associated with a significant risk of osteo-muscular and tendon pains in some body sites.

Overall, findings from the present study supported those of previous studies that concluded on a link between PSQ and MSDs. Several mechanisms might explain this association between PSQI and MSDs. Inadequate sleep triggers elevated blood cytokine levels and mediators of inflammation (11, 30), or alterations , or alterations in opioid/dopamine transmission, which can lead to diminished pain tolerance thresholds the neurotransmission system of opioid-dopamine, which can lead to reduced pain tolerance thresholds (34). PSQI is related to an increase in blood ghrelin levels, which rise at night due to acute sleep disturbance (35). Ghrelin then triggers the neuropeptide Y directly in the hypothalamus and indirectly inhibits neurons that produce proopiomelanocortin. Once activated, neuropeptide Y influences nociceptive processing in specific areas of the central nervous system, promoting antinociception at the spinal level and modulating pain perception within the brain (36).

Furthermore, β-endorphin, a derivative of proopiomelanocortin, is recognized as a crucial endogenous element of the antinociceptive system. Its analgesic action is facilitated through opioid receptors, whose activity is modulated by nitric oxide (37). From a physiological view point, ghrelin enhances nitric oxide synthesis, thereby amplifying the antinociceptive actions of endogenous opioids and demonstrating its involvement in central opioid pathways. Additionally, ghrelin acts as a potent anti-inflammatory mediator by suppressing inflammatory cytokines like IL-1β, IL-6 and TNF-α, which are linked with joint pain (38). In adolescents with PSQ, the sympathetic nervous system becomes activated, leading to reduced muscle relaxation, elevated muscle tone, and a heightened risk of MSDs (30).

Cardiorespiratory fitness was not significantly associated with musculoskeletal disorders (MSDs). This result contradicted that of Fonseca and de Azevedo, who demonstrated the protective effects of physical activity against MSDs. These results demonstrated that poor sleep has harmful effects on maximal oxygen consumption, reducing it and consequently reducing the preventive effects against the onset of MSDs (39). Consequently, aerobic exercise is recognized for its beneficial effects on musculoskeletal health by promoting bone remodeling and facilitating bone adaptation through cellular mechano transduction, which contributes to pain reduction (17). Also, it is known that aerobic exercises improve MSDs symptoms in all body regions by increasing both muscle and bone blood supply, reducing muscle tension, preserving joint movement, minimizing pain and/or injuries, and enhancing their repairment through analgesic effects both muscle and bone blood supply, reducing muscle tension, preserving movement of joints, minimizing pain and injuries, and enhancing their repair through analgesic effects (40). Also, regular practice of aerobic exercises induces production of mediators improving good sleep (18).

4.1. Limitations

This study highlighted the relationship between of PSQ and MSDs in adolescents, both in overall and according to body regions. A particular feature of this study was the focus on PSQI sleep components on MSDs and according to body regions. Although aerobic fitness is generally recognized for its protective role, it did not demonstrate any influence on MSD occurrence in this context. The strength of the present study stems from the use of the PSQI Questionnaire, a well-validated tool widely referenced in scientific literature. However, the findings should be considered within the framework of limitations. Firstly, the dependence on self-reported means there was no objective

method to verify the accuracy of each adolescent's responses, potentially leading to information bias and either underestimation or overestimation of some results. Moreover, transversal design of the study restricts its ability to determine causal links.

5. Conclusions

This study highlighted the high burden MSDs and their association with poor quality of sleep in adolescents. The present study revealed the intricate interplay between MSDs and PSQ. MSDs and PSQ may deteriorate health through the emergence of chronic diseases during adolescence even in adulthood. MSDs on the neck were associated with an increase of sleep subjectivity, latency, duration, quality, medication, and disturbances. Regarding sleep components, sleep disturbances was most associated with MSDs on neck, shoulders, lower back, knees, and hips/thighs. Also, this study did not demonstrate any protective effect of cardiorespiratory fitness against the occurrence of MSDs. As practical implications, PSQ is a major risk factor for MSDs. These joint and muscles pains will have an impact on the quality of life of adolescents with physical limitations. This could lead to a reduction in level of physical activities especially on CRF and expose adolescents to cardiometabolic diseases. These results underscored the imperative need for interventions to reduce MSDs, with particular emphasis on improving sleep quality in this young population.

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Authors' Contributions

Jerson Mekoulou Ndongo: Substantial contributions to the conception and design of the work; acquisition, analysis, and interpretation of data; drafting the work and reviewing it critically for important intellectual content. William Mbang Bian: Substantial contributions to the conception and design of the work; acquisition, analysis, and interpretation of data; drafting the work and reviewing it critically for important intellectual content. Abraham Sylvin Mefiré Rengou: Substantial contributions to the conception and design of the work; the acquisition, analysis, and interpretation of data; drafting the work and reviewing it critically for important intellectual content. Hassane Malam Moussa Ahmet: Substantial contributions to analysis and interpretation of data; drafting the work. Elysée Claude Bika Lele: Substantial contributions to the design of the work; analysis and interpretation of data; reviewing the work critically for important intellectual content. Emmanuel Guilou Njimongna Njoya: Substantial contributions to the conception and design of the work; acquisition of data; drafting the work. Samuel Honoré Mandengue: Substantial contributions to the conception and design of the work; acquisition of data; reviewing the work critically for important intellectual content. Bienvenu Bongue: Substantial contributions to the conception and design of the work; acquisition of data; reviewing the work critically for important intellectual content. Peguy Brice Assomo Ndemba: Substantial contributions to the conception and design of the work; acquisition of data; reviewing the work critically for important intellectual content. Clarisse Noel Ayina Ayina: Substantial contributions to the conception and design of the work; acquisition of data; drafting the work and reviewing it critically for important intellectual content. All authors have reviewed and approved the final manuscript and take responsibility for all aspects of the work, including questions regarding the accuracy or integrity of any part.

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Ethical Approval

The ethics committee of the University of Douala, Cameroon approved the present research with the code of 4158CEI-Udo/04/2024/M. The study was conducted in conformity with the recommendations of the Declaration of Helsinki, as revised in 1989. All adolescent participants provided informed consent, signed by their parents or legal tutors, before enrolment in the study.

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