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Original Article

Relationship between sleep and muscle strength among Chinese university students: a cross-sectional study

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Abstract

Objectives: Poor sleep quality and short sleep duration are associated with an increased risk for muscle mass reduction. Thus, they may also influence muscle strength. This study aimed to investigate the association between sleep quality and duration, and muscle strength in university students. **Methods:** This cross-sectional study comprised 10,125 university students aged 16-30 years. Handgrip strength was measured using a handheld digital dynamometer. Sleep quality and duration were measured using a self-reported questionnaire. **Results:** After adjusting for confounding factors, a positive association between sleep quality and muscle strength was observed in both male and female students. Moreover, men with shorter sleep duration (<6 hours) had poorer muscle strength than that of men who slept for 7-8 hours and over 8 hours in the final adjusted model. There was no significant difference in the association of sleep duration and muscle strength between men who slept 7-8 hours and those who slept for more than 8 hours. No significant association was observed between sleep duration and muscle strength in female students. **Conclusions:** Good sleep quality is associated with greater muscle strength, while short sleep duration may be a risk factor for decreased muscle strength in university students.

Keywords: Sleep Quality, Sleep Duration, Muscle Strength, Cross-Sectional Study, College Students

Introduction

Muscle weakness has consistently been reported as an independent risk factor for falls[1], hip fractures[2], and adverse physiological changes, such as glucose intolerance[3] and a loss of bone mineral density[4]. Further, handgrip strength as a representation of muscle strength is also a strong indicator of health status, based on the incidence of disability, morbidity, and mortality in adult populations[5-7]. Individuals who maintain greater handgrip strength are at a lower risk for disability and joint impairment. In addition, these individuals tend to live longer than those with low handgrip strength. A previous study has also demonstrated that even in middle-aged individuals, the risk of mortality in those with lower grip strength was more than twice the risk in those with higher grip strength[8].

Meanwhile, sleep is a homeostatic process and a periodic biological state that is crucial to physical and mental health[9]. Previous studies showed that both short (<7 hours) and prolonged (>8 hours) sleep duration are related to increased mortality[10], and increased risk of hypertension[11], diabetes[12], and obesity[13]. In addition, insufficient or non-restorative sleep may lead to inability to concentrate, cognitive deterioration and decreased quality of life[14-16]. Moreover, a recent study suggested that objective short sleep duration is associated with elevated inflammation in adolescents[17], and sleep disruptions are associated with impaired secretion of trophic factors such as insulin-like growth factor-1 (IGF-1)[18]. As inflammation is an important risk factor for decreased muscle strength, and IGF-1 is also an important modulator of muscle mass and function[19], we speculated that sleep status might be a factor that affects muscle strength. Although several studies demonstrated the relationship between sleep

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Table 1. Characteristics of male and female participants according to sleep quality[a].

	Sleep quality			Trend p[b]
	Poor	Normal	Good	
Male participants				
n	1090	3409	1752	
BMI (kg/m^2)	23.1 (22.9-23.4)[c]	23.2 (23.0-23.3)	23.3 (23.1-23.6)	0.269
Grade (%)				
First year	30.5	30.6	31.2	0.637
Second year	30.3	29.2	27.6	0.108
Third year	25.6	25.3	25.2	0.836
Fourth year	13.7	14.9	16.0	0.092
Minority race (%)	5.9	6.5	6.6	0.465
Physical activity (≥23METs h/week; %)	35.6	36.1	39.2	0.033
Living status (dormitory; %)	93.1	92.1	92.5	0.689
Smoking status (%)				
Smoker	20.6	19.8	19.3	0.420
Drinking status (%)				
Drinking everyday	5.9	6.6	4.7	0.086
Drink occasionally	30.8	27.8	30.3	0.937
Non-drinker	63.3	65.6	65.1	0.437
Depressive symptom (%)	18.3	19.4	19.6	0.430
Regular consumption of Hypnotic drug (%)	1.3	1.6	0.6	0.053
Female participants				
n	755	2100	1019	
BMI (kg/m^2)	21.2 (20.9-21.5)	21.2 (21.0-21.4)	21.2 (20.9-21.4)	0.799
Grade (%)				
First year	32.5	27.7	28.1	0.066
Second year	24.4	28.4	28.5	0.078
Third year	23.3	25.2	27.9	0.026
Fourth year	19.9	18.7	15.6	0.016
Minority race (%)	7.7	7.3	7.9	0.784
Physical activity (≥23METs h/week; %)	33.6	34	37.4	0.079
Living status (dormitory; %)	92.7	90.4	90.7	0.181
Smoking status (%)				
Smoker	2.0	2.0	2.6	0.379
Drinking status (%)				
Drinking everyday	5.2	5.0	3.3	0.051
Drink occasionally	21.5	18.6	26.4	0.003
Non-drinker	73.4	76.5	70.3	0.064
Depressive symptom (%)	18.0	19.5	18.8	0.725
Regular consumption of Hypnotic drug (%)	2.0	1.8	0.9	0.052

[a] *BMI: body mass index; PA: physical activity.*
[b] *Obtained using ANOVA for continuous variables and x^2 test for proportional variables.*
[c] *Mean; 95% CI in parentheses (all such values).*

and muscle mass, no study has yet shown the relationship between sleep duration and sleep quality, and muscle strength in young adults. Thus, we designed a cross-sectional study to investigate the relationship between sleep duration and quality, and muscle strength in Chinese college students.

Methods

Study population

The study was based on an annual physical examination, which was carried out for monitoring physical health of

Table 2. Characteristics of male and female participants according to sleep duration[a].

	Sleep duration (h/d)			Trend *p*[b]
	<7	7-8	>8	
Male participants				
n	1675	3324	1252	
BMI (kg/m^2)	23.1 (22.9-23.4)[c]	23.2 (23.1-23.4)	23.3 (23.0-23.5)	0.381
Grade (%)				
First year	30.5	30.8	30.8	0.839
Second year	28.7	29.1	28.7	0.991
Third year	26.0	24.9	25.6	0.739
Fourth year	14.8	15.1	14.9	0.898
Minority race (%)	5.5	6.8	6.7	0.146
Physical activity (≥23METs h/week; %)	37.4	34.7	41.7	0.050
Living status (dormitory; %)	92.5	92.2	92.8	0.791
Smoking status (%)				
Smoker	19.3	20.1	19.5	0.865
Drinking status (%)				
Drinking everyday	6.6	6.3	4.2	0.012
Drink occasionally	28.8	28.4	30.9	0.256
Non-drinker	64.7	65.3	64.9	0.874
Depressive symptom (%)	18.1	19.7	19.8	0.211
Regular consumption of Hypnotic drug (%)	1.3	1.5	0.7	0.269
Female participants				
n	1032	2147	695	
BMI (kg/m^2)	21.3 (21.0-21.5)	21.2 (21.0-21.3)	21.1 (20.8-21.4)	0.449
Grade (%)				
First year	28.2	29.5	27.2	0.781
Second year	27.0	27.5	28.9	0.411
Third year	25.7	24.9	27.2	0.577
Fourth year	19.1	18.1	16.7	0.207
Minority race (%)	8.2	7.0	8.3	0.890
Physical activity (≥23METs h/week; %)	32.1	34.9	38.7	0.005
Living status (dormitory; %)	92.1	90.4	91.1	0.373
Smoking status (%)				
Smoker	2.7	1.7	2.7	0.765
Drinking status (%)				
Drinking everyday	5.3	4.6	3.3	0.054
Drink occasionally	20.7	20.7	23.5	0.225
Non-drinker	73.9	74.7	73.2	0.832
Depressive symptom (%)	16.5	19.8	20.4	0.026
Regular consumption of Hypnotic drug (%)	1.9	1.6	0.9	0.090

[a] BMI: body mass index; PA: physical activity.
[b] Obtained using ANOVA for continuous variables and x^2 test for proportional variables.
[c] Mean; 95% CI in parentheses (all such values).

university students at Dalian Institute of Science and Technology. All students were invited to participate in physical examination. Those who had physical disability, cardiovascular diseases, respiratory diseases, or who had special reason that could not participate were excluded before physical examination. Participation rate was 91.8%. We invited all students who had undergone the physical examination in 2015 to participate in this study (n = 10,711).

Among these, 10,570 students agreed to participate and provided informed consent for their data to be analyzed. This study was approved by the Human Investigation Review Committee of Dalian Institute of Science and Technology.

We excluded subjects whose questionnaire data or physical function data were unavailable (n=445). Therefore, the final study population comprised 10,125 subjects (6,251 men and 3,874 women).

Measurement of sleep

We assessed sleep quality and duration by using a self-reported questionnaire including sleep-related questions. Students were asked to rate difficulties with initiating and maintaining sleep on a five-point scale: 1, <1 day per month; 2, 1-3 days per month; 3, 4-7 days per month; 4, 8-15 days per month; and 5, ≥16 days per month. A score of 1 or 2 indicated good sleep quality, 3 indicated normal sleep quality, and 4 or 5 indicated poor sleep quality. Sleep duration was assessed by self-reported sleep hours at night in the past month, and was then divided into 3 categories: <7 hours, 7-8 hours, and >8 hours. The use of hypnotics was assessed through the question "have you used hypnotic drugs in the past month?" the possible answers were "yes" and "no".

Measurement of muscle strength

Muscle strength was determined on the basis of handgrip strength and was measured using a dynamometer (TKK 5401, Takei Kiki Kogyo Co., Tokyo, Japan). The grip strength was measured twice for each hand. Students were asked to squeeze the handle as hard as possible in a standing position with the arm straight down. The maximum force applied was used in the analysis.

Measurement of other variables

Body mass index (BMI) was calculated as weight/height^2 (kg/m^2). Daily physical activity (PA) was determined using the International Physical Activity Questionnaire (IPAQ), and total daily PA was calculated as follows: METs × h/week[20]. PA was divided into two categories: 0-22.9 and ≥23 MET hours/week[21]. Depressive symptoms were assessed using the Self-rating Depression Scale (SDS). An SDS score ≥45 was defined as the depressed group[22]. Information on student age, sex, grade, living status, smoking and drinking status was obtained by conducting a questionnaire survey.

Statistical analysis

All statistical analyses were performed using SPSS/PC statistical software version 17.0 for windows (SPSS, Inc., Chicago, IL, USA). Grip strength was used as a dependent variable, and sleep quality and sleep duration were used as independent variables. Differences between the sleep categories were examined using analysis of variance for continuous variables and logistic regression analysis for proportional variables. ANCOVA was performed to examine the relationship between sleep status and grip strength in Model 1 and Model 2. Bonferroni-corrected p values were used to compare sleep quality and sleep duration between the groups. A p value <0.05 was considered statistically significant in all analyses.

Results

These cross-sectional data were obtained from 10,125 subjects (6,251 men [61.7%] and 3,874 women [38.3%]). Table 1 summarizes the characteristics of the students according to self-reported sleep quality. The proportion of male students who reported high physical activity significantly higher across the sleep quality categories (p for trend= 0.033). The proportion of female students in third year of university or those who occasionally drank alcohol was higher across the sleep quality categories (p for trend= 0.026, and 0.003, respectively). On the contrary, the proportion of female students in the fourth year of university was lower across the sleep quality categories (p for trend= 0.016).

The characteristics of the students according to daily sleep duration are presented in Table 2. The proportion of male students who drank alcohol every day was significantly lower across the sleep duration categories (p for trend= 0.012). The proportion of female students who reported high physical activity or had depressive symptoms was higher across the sleep duration categories (p for trend= 0.005, and 0.026, respectively).

Table 3 shows the adjusted association between sleep quality and grip strength. In Model 1 of male students, the grip strengths were 40.1 (95% CI; 39.7-40.6) newton, 41.3 (95% CI; 41.0-41.5) newton, and 42.1 (95% CI 41.7-42.4) newton in poor, normal, and good sleep quality categories, respectively (p for trend <0.001). The grip strength of female students in Model 1 were 25.3 (95% CI; 25.0-25.6) newton, 25.6 (95% CI; 25.4-25.7) newton, and 25.7 (95% CI; 25.4-26.0) newton for poor, normal, and good sleep quality categories, respectively (p for trend= 0.030). Moreover, in Model 2, an association similar to that observed in Model 1 was observed between sleep quality and grip strength in both male (p for trend <0.001) and female students (p for trend= 0.001).

Table 4 shows the adjusted association between sleep duration and grip strength. In Model 1 of male students, the grip strengths were 40.2 (95% CI; 39.9-40.6) newton, 41.8 (95% CI; 41.5-42.1) newton, and 41.4 (95% CI 41.0-41.8) newton for categories of sleep duration <7 hours, 7-8 hours, and >8 hours, respectively (p for trend <0.001). Grip strength was lower in the students in the <7 hour sleep duration category than that in students in the 7-8 hour and >8 hour sleep duration categories (Bonferroni-corrected p<0.05). In addition, this association did not change when we adjusted more confounding factors in Model 2 (p for trend <0.001). No significant association was found between sleep duration and grip strength in female students.

Table 3. Adjusted relationship between sleep quality and grip strength (newton)[a].

	Sleep quality			trend *p*[b]
	Poor	Normal	Good	
Men				
n.	1090	3409	1752	
Model 1[c]	40.1 (39.7-40.6)	41.3 (41.0-41.5)*	42.1 (41.7-42.4)*,†	<0.001
Model 2[d]	40.1 (39.6-40.5)	41.2 (40.9-41.4)*	42.4 (42.0-42.7)*,†	<0.001
Women				
n.	755	2100	1019	
Model 1[c]	25.3 (25.0-25.6)	25.6 (25.4-25.7)	25.7 (25.4-26.0)	0.030
Model 2[d]	25.2 (24.9-25.5)	25.5 (25.3-25.7)	25.9 (25.6-26.1)*	0.001

[a] Variables are expressed as estimated geometrics means (95% CI).
[b] Obtained using ANCOVA.
[c] Adjusted for body mass index and race.
[d] Further adjusted for grade, physical activity, living status, smoking and drinking habits, breakfast, depressive symptoms and Hypnotic drug.
** Significantly different to poor sleep quality, p<0.05 (Bonferroni-corrected).*
† Significantly different to normal sleep quality, p<0.05 (Bonferroni-corrected).

Table 4. Adjusted relationship between sleep duration and grip strength (newton)[a].

	Sleep duration (h/d)			trend *p*[b]
	< 7	7 - 8	>8	
Men				
n.	1675	3324	1252	
Model 1[c]	40.2 (39.9-40.6)	41.8 (41.5-42.1)*	41.4 (41.0-41.8)*	<0.001
Model 2[d]	40.1 (39.7-40.5)	41.7 (41.4-41.9)*	41.9 (41.4-42.5)*	<0.001
Women				
n.	1032	2147	695	
Model 1[c]	25.5 (25.2-25.7)	25.6 (25.4-25.8)	25.5 (25.2-25.8)	0.989
Model 2[d]	25.4 (25.1-25.7)	25.6 (25.4-25.7)	25.7 (25.4-26.1)	0.138

[a] Variables are expressed as estimated geometrics means (95% CI).
[b] Obtained using ANCOVA.
[c] Adjusted for body mass index and race.
[d] Further adjusted for grade, physical activity, living status, smoking and drinking habits, breakfast, depressive symptoms and Hypnotic drug.
** Significantly different to <7 hour sleep duration, p<0.05 (Bonferroni-corrected).*

Discussion

In the present study, we found that sleep quality was positively associated with muscle strength, and short sleep duration was associated with reduced muscle strength. Even after adjusting for a number of potentially confounding variables, these associations did not change.

To our knowledge, this is the first study to investigate the association between sleep duration and sleep quality, and muscle strength in young adults. A cross-sectional study including 1,196 elderly participants found that poor sleep quality is associated with not only reduced muscle mass, but also decreased grip strength in older women[23]. The results of the study partially agreed with those of the present study. However, in our study, we found a positive association between sleep quality and grip strength in both male and female college students.

A previous study demonstrated that increased IGF-1 is associated with improved sleep quality[24]. IGF-1 is an anabolic hormones that plays an important roles in protein synthesis and, thus, in maintenance of muscle mass[25]. Recent findings from an epidemiological study showed that low plasma IGF-1 levels are associated with poor knee extensor muscle strength and slow walking speed[26]. Moreover, IGF-1 is rapidly reduced under conditions of sleep deprivation[27]. Sleep deprivation is associated with two outcomes: increases in the secretion of catabolic hormones, such as cortisol[28,29], and changes in the pattern of rhythmic secretion of anabolic hormones,

such as testosterone[30]. These previous studies indicated that maintaining a good sleep quality and optimal sleep duration could increase muscle mass and prevent its loss. On the contrary, it has been proven that high muscle mass relates to high muscle strength[31]. Thus, we speculated that good sleep quality and optimal sleep duration are indirectly associated with higher muscle strength. However, significant association between sleep duration and grip strength was only found in male, but not in female. A possible explanation could be considered. Biological conditions unique to women, including menstrual cycles and female hormones, were suggested to be related to sleep pattern and sleep duration[32,33]. Whereas, several previous reports indicated that grip strength decreased during both the follicular and luteal phases[34]. In addition, delayed muscle recovery in female was found during menstrual phase[35]. It is considerable that menstrual cycles and female hormones might be an important mediator, which might influence the association between sleep duration and muscle strength in female.

Our study has some limitations. First, self-reported sleep quality and sleep duration was used in our analysis rather than actual measurement of sleep quality and duration. Thus, recall bias inevitably existed. Second, the cross-sectional design precludes defining causal relationships. Prospective or interventional studies are required to clarify the causality. Third, although we adjusted for a number of potential confounding variables, we could not exclude the possibility that other covariates may have influenced the association between sleep status and muscle strength.

The present people-based survey data indicated that sleep quality was positively associated with muscle strength, and short sleep duration was associated with an increased risk for reduction of muscle strength in college students. Considering that long sleep duration was not recommended, maintaining a sleep duration of 7-8 hours may be preferable for muscle strength. Reduced sleep quality and sleep duration might be potential risk factors for muscle strength. Further, epidemiologic investigations and interventional studies are required to ascertain whether these relationships are replicated in other populations.

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