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 falls¹, hip fractures², and adverse physiological changes, such as glucose intolerance³ and a loss of bone mineral density⁴. 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 populations⁵-⁷. 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 strength⁸.

Meanwhile, sleep is a homeostatic process and a periodic biological state that is crucial to physical and mental health⁹. Previous studies showed that both short (<7 hours) and prolonged (>8 hours) sleep duration are related to increased mortality⁰, and increased risk of hypertension¹¹, diabetes¹², and obesity¹³. In addition, insufficient or non-restorative sleep may lead to inability to concentrate, cognitive deterioration and decreased quality of life¹⁴-¹⁶. Moreover, a recent study suggested that objective short sleep duration is associated with elevated inflammation in adolescents¹⁷, 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 function¹⁹, we speculated that sleep status might be a factor that affects muscle strength. Although several studies demonstrated the relationship between sleep
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 1. Characteristics of male and female participants according to sleep quality. |
|-------------------------------------|-------------------------------------|-------------------------------------|
| Male participants                   | Sleep quality                      | Trend p<sup>a</sup>                  |
|                                    | Poor                                | Normal                              | Good                                |
| n                                   | 1090                                | 3409                                | 1752                                |
| BMI (kg/m²)                          | 23.1 (22.9-23.4)<sup>c</sup>        | 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/m²)                          | 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                              |

<sup>a</sup> BMI: body mass index; PA: physical activity.

<sup>b</sup> Obtained using ANOVA for continuous variables and χ² test for proportional variables.

<sup>c</sup> 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).

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

| Sleep duration (h/d) | Male participants | Female participants |
|----------------------|-------------------|---------------------|
|                      | <7 | 7-8 | >8 | |                      |<7 | 7-8 | >8 |
| n                    | 1675 | 3324 | 1252 | | 1032 | 2147 | 695 |
| BMI (kg/m²)          | 23.1 (22.9-23.4)c | 23.2 (23.1-23.4) | 23.3 (23.0-23.5) | 0.381 | 21.3 (21.0-21.5) | 21.2 (21.0-21.3) | 21.1 (20.8-21.4) | 0.449 |
| Grade (%)            |                 |                  |               |     |                 |                  |               |     |
| First year           | 30.5 | 30.8 | 30.8 | 0.839 | 28.2 | 29.5 | 27.2 | 0.781 |
| Second year          | 28.7 | 29.1 | 28.7 | 0.991 | 27.0 | 27.5 | 28.9 | 0.411 |
| Third year           | 26.0 | 24.9 | 25.6 | 0.739 | 25.7 | 24.9 | 27.2 | 0.577 |
| Fourth year          | 14.8 | 15.1 | 14.9 | 0.898 | 19.1 | 18.1 | 16.7 | 0.207 |
| Minority race (%)    | 5.5 | 6.8 | 6.7 | 0.146 | 6.2 | 7.0 | 8.3 | 0.890 |
| Physical activity (≥23METs h/week; %) | 37.4 | 34.7 | 41.7 | 0.050 | 32.1 | 34.9 | 38.7 | 0.005 |
| Living status (dormitory; %) | 92.5 | 92.2 | 92.8 | 0.791 | 92.1 | 90.4 | 91.1 | 0.373 |
| Smoker (%)           | 19.3 | 20.1 | 19.5 | 0.865 | 2.7 | 1.7 | 2.7 | 0.765 |
| Drinking status (%)  |                 |                  |               |     |                 |                  |               |     |
| Drinking everyday    | 6.6 | 6.3 | 4.2 | 0.012 | 5.3 | 4.6 | 3.3 | 0.054 |
| Drink occasionally   | 28.8 | 28.4 | 30.9 | 0.256 | 20.7 | 20.7 | 23.5 | 0.225 |
| Non-drinker          | 64.7 | 65.3 | 64.9 | 0.874 | 73.9 | 74.7 | 73.2 | 0.832 |
| Depressive symptom (%) | 18.1 | 19.7 | 19.8 | 0.211 | 16.5 | 19.8 | 20.4 | 0.026 |
| Regular consumption of Hypnotic drug (%) | 1.3 | 1.5 | 0.7 | 0.269 | 1.9 | 1.6 | 0.9 | 0.090 |

a BMI: body mass index; PA: physical activity.
b Obtained using ANOVA for continuous variables and χ² test for proportional variables.
c Mean; 95% CI in parentheses (all such values).
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/height² (kg/m²). Daily physical activity (PA) was determined using the International Physical Activity Questionnaire (IPAQ), and total daily PA was calculated as follows: METs × h/week²⁰. PA was divided into two categories: 0-22.9 and ≥23 MET hours/week²¹. Depressive symptoms were assessed using the Self-rating Depression Scale (SDS). An SDS score ≥45 was defined as the depressed group²². 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.
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\(^\text{23}\). 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\(^\text{24}\). IGF-1 is an anabolic hormones that plays an important roles in protein synthesis and, thus, in maintenance of muscle mass\(^\text{25}\). 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\(^\text{26}\). Moreover, IGF-1 is rapidly reduced under conditions of sleep deprivation\(^\text{27}\). Sleep deprivation is associated with two outcomes: increases in the secretion of catabolic hormones, such as cortisol\(^\text{28,29}\), and changes in the pattern of rhythmic secretion of anabolic hormones.

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**Table 3. Adjusted relationship between sleep quality and grip strength (newton)\(^a\).**

| Sleep quality | Men | Women |
|---------------|-----|-------|
| Poor | Normal | Good | Poor | Normal | Good |
| n. | 1090 | 3409 | 1752 | 755 | 2100 | 1019 |
| Model 1\(^c\) | 40.1 (39.7-40.6) | 41.3 (41.0-41.5)* | 42.1 (41.7-42.4)** | 25.3 (25.0-25.6) | 25.6 (25.4-25.7) | 25.7 (25.4-26.0) |
| Model 2\(^d\) | 40.1 (39.6-40.5) | 41.2 (40.9-41.4)* | 42.4 (42.0-42.7)** | 25.2 (24.9-25.5) | 25.5 (25.3-25.7) | 25.9 (25.6-26.1)* |

\(^{a}\) Variables are expressed as estimated geometric 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).

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**Table 4. Adjusted relationship between sleep duration and grip strength (newton)\(^a\).**

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

\(^{a}\) Variables are expressed as estimated geometric 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).
such as testosterone. 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. 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. Whereas, several previous reports indicated that grip strength decreased during both the follicular and luteal phases. In addition, delayed muscle recovery in female was found during menstrual phase. 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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References

1. Campbell A J, Borrie M J, Spears G F. Risk factors for falls in a community-based prospective study of people 70 years and older. J Gerontol 1989;44(4):M112-7.
2. Aniansson A, Zetterberg C, Hedberg M, Henriksson K G. Impaired muscle function with aging. A background factor in the incidence of fractures of the proximal end of the femur. Clin Orthop Relat Res 1984(191):193-201.
3. Bloesch D, Schutz Y, Breitenstein E, Jequier E, Felber J P. Thermogenic response to an oral glucose load in man: comparison between young and elderly subjects. J Am Coll Nutr 1988;7(6):471-83.
4. Sinaki M, McPhee MC, Hodgson SF, Merritt JM, Offord KP. Relationship between bone mineral density of spine and strength of back extensors in healthy postmenopausal women. Mayo Clin Proc 1986;61(2):116-22.
5. Giampaoli S, Ferrucci L, Cecchi F, Lo Noce C, Poce A, Dima F, et al. Hand-grip strength predicts incident disability in non-disabled older men. Age Ageing 1999;28(3):283-8.
6. Hughes S, Gibbs J, Dunlop D, Edelman P, Singer R, Chang R W. Predictors of decline in manual performance in older adults. J Am Geriatr Soc 1997;45(8):905-10.
7. Laukkonen P, Heikkinen E, Kauppinen M. Muscle strength and mobility as predictors of survival in 75-84-year-old people. Age Ageing 1995;24(6):468-73.
8. Fujita Y, Nakamura Y, Hiraoka J, Kobayashi K, Sakata K, Nagai M, et al. Physical-strength tests and mortality among visitors to health-promotion centers in Japan. J Clin Epidemiol 1995;48(11):1349-59.
9. Velayos JL, Moleres F J, Iruij AM, Yllanes D, Paternain B. [Anatomical basis of sleep]. An Sist Sanit Navar 2007;30 Suppl 1:7-17.
10. Hublin C, Partinen M, Koskenvuo M, Kaprio J. Sleep and mortality: a population-based 22-year follow-up study. Sleep 2007;30(10):1245-53.
11. Gottlieb DJ, Redline S, Nieto FJ, Baldwin CM, Newman AB, Resnick HE, et al. Association of usual sleep duration with hypertension: the Sleep Heart Health Study. Sleep 2006;29(8):1009-14.
12. Gottlieb DJ, Punjabi NM, Newman AB, Resnick HE, Redline S, Baldwin CM, et al. Association of sleep time with diabetes mellitus and impaired glucose tolerance. Arch Intern Med 2005;165(8):863-7.
13. Taheri S, Lin L, Austin D, Young T, Mignot E. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. PLoS Med 2004;1(3):e62.
14. Ancoli-Israel S, Cooke JR. Prevalence and comorbidity of insomnia and effect on functioning in elderly populations. J Am Geriatr Soc 2005;53(7 Suppl):S264-71.
15. Cooke JR, Ancoli-Israel S. Normal and abnormal sleep in the elderly. Handb Clin Neurol 2011;98:653-65.
16. Goel N, Rao H, Durmer JS, Dinges DF. Neurocognitive consequences of sleep deprivation. Semin Neurol 2009;29(4):320-39.
17. Fernandez-Mendoza J, Baker JH, Vgontzas AN, Gaines J, Liao D, Bixler EO. Insomnia symptoms with objective short sleep duration are associated with systemic inflammation in adolescents. Brain Behav Immun 2017;61:110-6.
18. Jarrett DB, Greenhouse JB, Miewald JM, Fedorka IB, Kupfer DJ. A reexamination of the relationship between growth hormone secretion and slow wave sleep using delta wave analysis. Biol Psychiatry. 1990;27(5):497-509.
19. Borst SE, Lowenthal DT. Role of IGF-I in muscular atrophy of aging. Endocrine. 1997;7(1):61-3.
20. Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth.
ML. Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003;35(8):1381-95.
21. Ishikawa-Takata K, Tabata I. Exercise and Physical Activity Reference for Health Promotion 2006 (EPAR2006). J Epidemiol 2007;17(5):177.
22. Cui Y, Huang C, Momma H, Ren Z, Sugiyama S, Guan L, et al. Consumption of low-fat dairy, but not whole-fat dairy, is inversely associated with depressive symptoms in Japanese adults. Soc Psychiatry Psychiatr Epidemiol 2017.
23. Buchmann N, Spira D, Norman K, Demuth I, Eckardt R, Steinhagen-Thiessen E. Sleep, Muscle Mass and Muscle Function in Older People. Dtsch Arztebl Int 2016;113(15):253-60.
24. Rusch H L, Guardado P, Baxter T, Myśliwiec V, Gill J M. Improved Sleep Quality is Associated with Reductions in Depression and PTSD Arousal Symptoms and Increases in IGF-1 Concentrations. J Clin Sleep Med 2015;11(6):615-23.
25. Dattilo M, Antunes HK, Medeiros A, Monico Neto M, Souza HS, Tufik S, et al. Sleep and muscle recovery: endocrinological and molecular basis for a new and promising hypothesis. Med Hypotheses 2011;77(2):220-2.
26. Cappola AR, Bandeen-Roche K, Wand GS, Volpato S, Fried LP. Association of IGF-I levels with muscle strength and mobility in older women. J Clin Endocrinol Metab 2001;86(9):4139-46.
27. Everson CA, Crowley WR. Reductions in circulating anabolic hormones induced by sustained sleep deprivation in rats. Am J Physiol Endocrinol Metab 2004;286(6):E1060-70.
28. von Treuer K, Norman TR, Armstrong SM. Overnight human plasma melatonin, cortisol, prolactin, TSH, under conditions of normal sleep, sleep deprivation, and sleep recovery. J Pineal Res 1996;20(1):7-14.
29. Weitzman ED, Zimmerman JC, Czeisler CA, Ronda J. Cortisol secretion is inhibited during sleep in normal man. J Clin Endocrinol Metab 1983;56(2):352-8.
30. Luboshitzky R, Zabari Z, Shen-Orr Z, Herer P, Lavie P. Disruption of the nocturnal testosterone rhythm by sleep fragmentation in normal men. J Clin Endocrinol Metab 2001;86(3):1134-9.
31. Kim SE, Hong J, Cha JY, Park JM, Eun D, Yoo J, et al. Relative appendicular skeletal muscle mass is associated with isokinetic muscle strength and balance in healthy collegiate men. J Sports Sci 2016;34(21):2114-20.
32. Krishnan V, Collop NA. Gender differences in sleep disorders. Curr Opin Pulm Med 2006;12(6):383-9.
33. Rasmussen BK. Migraine and tension-type headache in a general population: precipitating factors, female hormones, sleep pattern and relation to lifestyle. Pain 1993;53(1):65-72.
34. Davies BN, Elford JC, Jamieson KF. Variations in performance in simple muscle tests at different phases of the menstrual cycle. J Sports Med Phys Fitness 1991;31(4):532-7.
35. Oosthuyse T, Bosch AN. The Effect of Gender and Menstrual Phase on Serum Creatine Kinase Activity and Muscle Soreness Following Downhill Running. Antioxidants (Basel) 2017;6(1).