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SCIENTIFIC INVESTIGATIONS

Relationship between Long Sleep Duration and Functional Capacities in Postmenopausal Women

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Study Objective: The purpose of the present study was to examine the relationship between long sleep duration and functional capacities.

Methods: We conducted a cross-sectional study at the Department of Kinanthropology at the University of Quebec at Montreal. Forty eight non-frail postmenopausal women aged between 49 to 75 years were recruited using advertisements in local papers. Body weight, body mass index, fat mass, skeletal muscle mass, number of steps per day, SF-36 total (healthy questionnaire), resting metabolic rate, total energy intake, sleep duration, knee extensor strength (dynamometer), chair stand test and balance opened eyes test were measured.

Results: We found a significant negative correlation between hours of sleep and functional capacity: chair stand test ($r = -0.33$, $p = 0.02$), balance opened eyes test ($r = -0.45$, $p = 0.001$), muscle strength ($r = -0.43$, $p = 0.002$) and skeletal muscle mass ($r = -0.39$, $p = 0.007$). In addition, long sleepers (> 9 h) had significantly lower values for skeletal muscle mass ($p = 0.03$), muscle strength ($p = 0.01$), chair stand test ($p = 0.03$), and balance opened eyes test ($p = 0.001$). Finally, linear regression analysis showed that sleep duration was an independent predictor of the chair stand test ($p = 0.024$), balance opened eyes test ($p = 0.001$), and muscle strength ($p = 0.035$) in our cohort.

Conclusion: Long sleepers were associated with lower functional capacities in our cohort of sedentary postmenopausal women.

Keywords: Chair stand test, balance opened eyes test, muscle strength and skeletal muscle mass

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The optimal sleep duration recommended is between 7 and 8 hours per night for maintaining good health.[1,2] Accordingly, many studies have shown that sleep deprivation (< 7 h per day) may be associated with obesity, metabolic complications, and type 2 diabetes.[3,4] Indeed, there is emerging evidence to suggest that long sleep duration (> 9 h per day) could be associated with weight gain.[5] Moreover, an increase in sleep duration may increase the risk of metabolic complications, type 2 diabetes, and mortality.[2,6,7] However, the potential mechanism(s) that could explain this relationship is unclear, thus, more attention should be given to the negative effects of long sleep duration. Furthermore, several studies have shown that overweight and obesity may be associated with the development of functional disabilities.[8-11] For example, excess body weight was associated with higher risk of impaired physical function such as poorer performance in the Short Physical Performance Battery (SPPB) test, which includes balance and chair stands tests.[11] In addition, weight loss has been reported to improve functional parameters in older obese individuals.[12]

Presently, the possible link between long sleep duration and functional capacities is poorly understood. In fact, no data appears to be currently available on the relationship between long sleep duration and functional capacities. Knowledge of a relationship between these variables may help us better understand the risk of disease (e.g., type 2 diabetes) and/or mortality, at least in part, of an individual and as such provide useful information to health professionals. Therefore, the purpose of the present study was to examine the relationship between long sleep duration and functional capacities in a well-characterized population of sedentary postmenopausal women, a group at increased risk for developing functional capacities. Based on the study of Patel et al.,[6] which showed negative health outcomes in long sleepers, we hypothesized that long (> 9 h) sleep duration would be associated with lower functional capacities.

BRIEF SUMMARY

Current Knowledge/Study Rationale: There is emerging evidence to suggest that long sleep duration (> 9 h per day) could be associated with increase the risk of metabolic complications, type 2 diabetes, and mortality. The possible link between long sleep duration and functional capacities is poorly understood. Knowledge of a relationship between these variables may help us better understand the risk of disease (e.g., type 2 diabetes) and/or mortality, at least in part, of an individual and as such provide useful information to health professionals.

Study Impact: Long sleepers were associated with lower functional capacities in our cohort of sedentary postmenopausal women. These results have interesting implications for planning effective intervention programs for postmenopausal women. That is, health professionals could consider planning intervention programs that target the improvement of sleep duration and/or functional capacities.

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METHODS

Subjects

Forty-eight non-frail postmenopausal women aged between 49-85 years (mean: 61.0 ± 6 y) were recruited using advertisements in local papers and communities. It should be noted that none of our participants were identified as frail, which was based on the criteria of Fried et al.[13] To be included in the study, women had to meet the following criteria: no major physical incapacities (classified as autonomous regarding to the 18 activities of daily living[14]), no history of cardiovascular diseases and diabetes, no medication that could influence metabolism (except hormonal therapy), non-smoker, moderate drinker (< 2 drinks/day), body mass index (BMI) of 18.5 to 35 kg/m^2, stable weight (± 2 kg) for the last 6 months, absence of menses for the past 12 months, and sedentary (< 2 h/week of structured exercise). All procedures were approved by the Ethics Committee of the Department of Kinanthropology of the University of Quebec at Montreal. All participants were fully informed about the nature, goal, procedures and risks of the study, and gave their informed consent. This cross-sectional study took place from January 2010 to March 2010. Subjects presented themselves to the laboratory at 07:00, and all of the evaluations were performed on the same day.

Design

A phone interview was conducted to screen for the aforementioned inclusion criteria. After screening, women were invited for a visit to the Department of Kinanthropology at the University of Quebec at Montreal. After their arrival, body composition was measured in a fasting state, followed by functional capacity tests and muscle strength assessment.

Measurements

Anthropometric Measurements

Body Weight

Body weight (BW) was determined using an electronic scale (Omron HBF-500CAN, USA). Height was measured using stadiometer (Seca, USA) affixed to the wall. BMI was calculated: BW kg/height (m^2). Waist circumference (WC) was measured to the nearest 0.5 cm by using a non-elastic plastic tape with the participant standing upright.

Body Composition

Fat mass (FM) percentage was measured by bioelectrical impedance analysis (BIA) (Omron HBF-500CAN, USA).[15] The measurement was taken in the early morning after an overnight fast (food and liquid). Whole-body BIA measurements were taken with the participant standing upright, barefoot on the scale, arms stretched out in a 90° position, holding the handle of the device. In our laboratory, the coefficient of variation for repeated measures of body composition in 10 young women was 0.5% for fat mass. At the present time, BIA appears to be the best clinical method to analyze body composition.[16]

Skeletal Muscle Mass

Body resistance was measured by BIA. The measurements were taken in the early morning after an overnight fast (food and liquid). In our laboratory, the coefficient of variation for repeated measures of body resistance in 10 young women was 1%. Skeletal muscle mass (SM) was estimated using the validated equation of Janssen et al.[17]:

Skeletal muscle mass (*kg*) = (Height (cm^2) / *Resistance* (Ω) × 0.401) + (sex (female = 0) × 3.825) + (age (years) × 0.071) + 5.102

Number of Steps

The number of steps was assessed using a pedometer (Suzuken, Lifecorder PLUS (NL-2160), New Lifestyles Inc, Japan). The Lifecorder PLUS NL-2160 is a uniaxial pedometer that has been shown to be valid, reliable, and is recommended for applied physical activity research.[18] The pedometer was attached to the waist. Participants carried the pedometer for 7 consecutive days. Strycker et al.[19] showed that a 7-day period was sufficient to assess usual activity.

Short-Form 36-Item Health Survey Health Status Questionnaire (SF36)

This questionnaire consisted of 36 items divided into 8 dimensions: vitality, physical functioning, bodily pain, general health perception, physical role functioning, emotional role functioning, social role functioning, and mental health.[20] The total score was calculated, ranging from 0 to 100, with higher scores indicating a higher quality of life. The SF-36 has been shown to be reliable and valid and is recommended for older individuals.[21]

Resting Energy Expenditure (REE)

REE was measured using an indirect calorimeter system (Moxus, AEI Technologies, IL, USA). The measurements were taken in the early morning after an overnight fast, under standardized conditions, with the person lying awake, completely at rest and comfortably supine on a bed, and her head under a transparent ventilated canopy, in a thermally neutral environment. Respiratory gas samples were measured every 15 sec for 30 to 35 min; only measurements from steady states were considered for the analysis.[22] The calorimeter was calibrated daily before starting each test. The flow rate was calibrated with a 3-L syringe. In our laboratory, the coefficient of variation for repeated measures of REE in 10 young women was 3.5%.

Dietary Intake

Each participant was instructed to maintain normal dietary habits throughout the period of data collection.[23] Participants were provided with a food scale and instructed on how to complete a 3-day dietary record. Diets were recorded over 3 consecutive days, including 1 weekend day. It has been demonstrated that a 3-day dietary record is valid to estimate dietary intakes in older adults without cognitive impairments.[23] Dietary analyses were completed by using the Candat System software (version 8.0; Candat, London, ON, Canada) to determine daily intake of energy.

Sleep Duration (Hours) and Sleep Quality

Each participant self-reported for 7 days the time they went to sleep and the time they woke up. The mean sleep duration

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Table 1—Physical and functional characteristics of the 48 participants

Variables	Normal sleepers (n = 24)	Long sleepers (n = 24)	p value
Age (yr)	59 ± 5	62 ± 7	0.17
Poids (kg)	69 ± 13	66 ± 11	0.27
Body mass index (kg/m^2)	27.3 ± 5.1	26.0 ± 4.1	0.34
Fat mass (%)	39.9 ± 7.1	39.0 ± 6.4	0.63
Waist circumference (cm)	88.1 ± 12.3	87.8 ± 10.7	0.93
Skeletal muscle mass (kg)	16.4 ± 2.5	14.9 ± 1.9	0.03
Sleep duration (h)	7.9 ± 0.6	9.5 ± 0.3	< 0.001
Muscle strength (N)	476 ± 105	400 ± 92	0.01
Chair stand test (nb)	12.7 ± 2.9	11.1 ± 2.2	0.03
Balance opened eyes (sec)	55.1 ± 13.2	35.3 ± 23.9	0.001

Values are mean ± SD.

in hours was then calculated. Thereafter, we distributed the women in 2 groups: normal sleepers (7-8.5 h of sleep) and long sleepers (> 9 h of sleep). Self-reported sleep quality was assessed using the following question: "In the past 7 days, what was your level of sleep quality?" This question was scored between 0-3. A lower value represents a better score. It should be noted that in our cohort, only 3 participants had reported a sleeping time < 7 h. Thus, these subjects were excluded from the analysis.

Muscle Strength

Knee extensors strength was measured by the maximum isometric strength of the knee extensors assessed at 90° of knee flexion using the Kin Com 5000 dynamometer (Chattecx Corporation, Chattanooga, TN). Isometric testing using the Kin Com dynamometer has been shown to be accurate and reproducible between testing days.[24] Participants were seated in a standardized position of 90° of hip flexion and stabilized with waist and thigh straps. The lever arm axis of rotation was aligned with the lateral femoral condyle for each woman. Participants performed 2 submaximal trials to ensure familiarization with the protocol and testing apparatus. Participants were then instructed to perform 3 trials of maximal effort isometric knee extension lasting 5 sec, separated by 60 sec of rest. The maximum force output from the 3 trials was recorded.

Functional Capacities

(1) The chair stand test consisted of standing completely up from a chair without arm rests, then completely back down, with the arms crossed at the wrists and held close to the chest, as fast as possible for a 20-sec period; and (2) the one-leg stance test consisted of standing on one leg for as long as possible, with the arms along the side of the body. The test was interrupted after 60 sec or if the participant touched the floor with the raised leg. The measures were repeated with the right and left leg and with open eyes. The best performance regardless of the leg used was recorded.

Statistical Analysis

Results are presented as means ± SD. Normality was verified using the Kurtosis-test. An independent *t*-test was performed to compare normal and long sleepers. Using percentiles and box-plots no outliers were identified for BMI and waist circumference in both groups. Marginal estimates of functional capacities adjusted for skeletal muscle mass or muscle strength were calculated with ANCOVA (univariate general linear model). Pearson correlations were then performed to examine the relationships between sleep hours and functional capacities. Finally, we performed a stepwise linear regression analysis to identify predictors of the chair stand test, the balance opened eyes test, and muscle strength. Independent variables considered in the final model for the chair stand test, the balance opened eyes test, and muscle strength were sleep duration, skeletal muscle mass, % fat mass, age, and number of steps. p values < 0.05 were considered statistically significant. Analyses were performed using SPSS 19.0 software (Chicago, IL).

RESULTS

The physical and functional characteristics of normal and long sleepers are presented in **Table 1**. We observed no differences between groups for age (p = 0.17), weight (p = 0.27), body mass index (p = 0.34), and % fat mass (p = 0.63). By design, both groups were significantly different for sleep duration. Moreover, we observed a significant difference between groups for skeletal muscle mass (p = 0.03), muscle strength (p = 0.01), chair stand test (p = 0.03), and balance opened eyes test (p = 0.001). In addition, there was no difference for age of menopause (p = 0.75) and age of menarche (p = 0.92) between groups.

Interestingly, when statistically controlling for muscle strength, significant differences in the chair stand test between the groups were abolished. However, when the balance opened eyes test was adjusted for muscle strength, statistical significance still persisted among groups. Finally, when the chair stand test and balance opened eyes test was adjusted for skeletal muscle mass, statistical significance still persisted among groups.

Table 2 shows Pearson correlations between sleep hours and functional capacities. We found a significant negative correlation between sleep hours with the chair stand test (r = −0.33, p = 0.02), balance opened eyes test (r = −0.45, p = 0.001), muscle strength (r = −0.43, p = 0.002), and skeletal muscle mass (r = −0.39, p = 0.007). Moreover, skeletal muscle mass was significantly associated with muscle strength (r = 0.46, p < 0.001).

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In addition, we performed a stepwise regression analysis to identify independent predictor of functional capacities. **Table 3** illustrates the summary of the model. The present results show that sleep duration was the primary independent predictor of the chair stand test and the balance opened eyes test, explaining 10.7% and 20.3% of the variance, respectively. In addition, skeletal muscle mass (21%) and sleep duration (7.5%) were independent predictors of muscle strength, collectively explaining 28.5% of the variance. Furthermore, we performed another model for each of our 3 outcomes without skeletal muscle mass as an independent variable. We noted that for the chair stand test and balance opened eyes test, the results are identical between both models. However, for muscle strength, sleep duration was the only variable that predicts muscle strength with a unique variance of 18.4%

Finally, potential explanatory variables between normal and long sleepers are shown in **Table 4**. We noted no difference between number of steps per day (p = 0.7), self-reported sleep quality (p = 0.44), SF-36 total (p = 0.15), resting metabolic rate (p = 0.27), and total energy intake (p = 0.61).

DISCUSSION

Long sleep duration seems to be associated with weight gain, an increase risk of metabolic complications, type 2 diabetes, and mortality.[2,6,7] However, the potential mechanism(s) that could explain this relationship is unclear; thus, more attention should be given to the negative effects of long sleep duration. Therefore, the aim of the present study was to examine the relationship between long sleep duration and functional capacities in sedentary postmenopausal women, which may provide new insights into potential mechanisms that could explain, at least in part, the relationship between long sleep duration and negative health outcomes. Thus, we hypothesized that long sleep duration (> 9 h) would be associated with lower functional capacities. Results from the present study support our hypothesis. That is, we observed significant negative relationships between long sleep duration with the chair stand test, balance opened eyes test, and muscle strength. The strength of this relationship is reinforced by the fact that the relationship is present even in a homogenous population of postmenopausal women with similar body fat percentages and with no major physical incapacities. Furthermore, we found that the chair stand test, balance opened eyes test, and muscle strength values were significantly lower by ~13%, 36%, and 16%, respectively, in long sleepers compared to normal sleepers, despite no differences in sleep quality. Finally, results from the stepwise regression analysis showed that sleep duration was an independent predictor of the chair stand test, balance opened eye test, and muscle strength. It should be noted that sleep duration accounted for the greatest source of unique variance for the chair stand test and the balance opened eye test in our cohort. This suggests that long sleep duration could contribute to lower values in the chair stand test, balance opened eyes test, and muscle strength. These results have interesting implications for planning intervention programs for postmenopausal women. That is, health professionals could consider planning intervention programs that target the improvement of sleep duration and/or functional capacities. It should be noted that sleep deprivation is also association with lower functional capacities.[25] Thus, it appears that normal functional capacities are associated with an optimal range of sleep duration.

What are the potential mechanisms that could explain the lower levels of functional capacities in long sleepers for the chair stand and opened eyes tests? Lower skeletal muscle mass content has been reported to be associated with poor functional capacities, which could lead to an increase risk for falls and disabilities.[26,27] Moreover, several studies have shown that muscle strength may be associated with lower levels of functional capacities, which may also lead to an increase risk in falls and dis-

Table 2—Pearson correlations between functional capacities and sleep duration (n = 48)

Variables	Sleep hours
Chair stand test	r = −0.33, p = 0.02
Balance opened eyes	r = −0.45, p = 0.001
Knee extensor strength	r = −0.43, p = 0.002
Skeletal muscle mass	r = −0.39, p = 0.007

Table 3—Stepwise regression analysis regarding independent predictors of functional capacities

Dependent variable	Step	Independent variable	Partial r^2	Total r^2 cumulative	Beta coefficients	p value
Chair stand test	1	Sleep duration	0.107	0.107	−0.326	0.024
Balance opened eyes	1	Sleep duration	0.203	0.203	−0.451	0.001
Muscle strength	1	Skeletal muscle mass	0.210	0.210	0.344	0.015
	2	Sleep duration	0.075	0.285	−0.279	0.035

Table 4—Potential explanatory variables between normal and long sleepers

Variables	Normal sleepers (n = 24)	Long sleepers (n = 24)	p value
Number of steps per day	8550 ± 3703	8926 ± 2969	0.7
SF 36 total (/100)	85 ± 19	78 ± 14	0.15
Self-reported sleep quality (/3)*	0.54 ± 0.66	0.71 ± 0.81	0.44
Resting metabolic rate (Kcal)	1514 ± 267	1431 ± 242	0.27
Total energy intake (Kcal)	2048 ± 334	2122 ± 615	0.61

Values are mean ± SD. *A lower value represents a better score.

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abilities.[28-31] In the present study, we noted that muscle strength and skeletal muscle mass were significantly lower in long sleepers, which could be potential mechanisms in explaining the poorer performance in the chair stand and balance opened eyes tests in long sleepers. Accordingly, when statistically controlling for muscle strength (but not for skeletal muscle mass), significant differences in the chair stand test between the groups were abolished. Although this finding is not totally surprising, this potentially underscores the importance of muscle strength as a modulating factor. However, when the balance opened eyes test was adjusted for muscle strength or skeletal muscle mass, statistical significance still persisted among groups, suggesting that these parameters are not the main mediators. A potential mechanism that may explain the relationship between sleep duration and the balance opened eyes test could be physical activity levels. A longer sleep time may create less of an opportunity to engage in physical activity. In support of this hypothesis, individuals who slept more than 9 hours per day had 15% less physical activity per week than those sleeping 7 or 8 hours per day.[32]

The present study has several limitations. Our cohort is composed of only sedentary postmenopausal women. Thus, our results are limited to this population. Furthermore, we used a cross-sectional approach, which does not allow us to conclude to any causal associations between long sleep duration and functional capacities in our cohort.

In conclusion, long sleepers were associated with lower functional capacities in our cohort of sedentary postmenopausal women. This relationship may be mediated by lower muscle strength for the chair stand test. This suggests that a better understanding of the interrelationship between sleep duration and functional capacities could help guide health professionals in the development of effective intervention programs, which may lead to a lower risk for falls.

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