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SCIENTIFIC INVESTIGATIONS

Association between objectively measured sleep duration and physical function in community-dwelling older adults

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Study Objectives: The aim of this research was to investigate the relationships between objectively measured sleep duration and physical function in older adults.

Methods: We recruited community-dwelling older adults aged ≥ 60 years old in Taipei City, Taiwan. Sleep duration was measured with accelerometers and recorded as the total hours of sleep per night for each participant. The following physical functions were assessed: 1) grip strength (measured by handgrip dynamometer), 2) balance (1-leg standing test), 3) lower body strength (5-timed chair stand), 4) basic mobility (timed up and go test), 5) gait speed (5-m walk test). The relationships between sleep duration and physical function outcomes were analyzed using generalized additive models, controlling for objectively measured sedentary behavior and moderate-to-vigorous physical activity, and other sociodemographic variables.

Results: A total of 121 older adults (men = 28.9%; mean age = 70.0 ± 5.0 years) was included in this study. A positive association of sleep duration with grip strength was found after adjusting for covariates (*P* = .005). No significant associations were observed between sleep duration and the other physical function outcomes.

Conclusions: For older adults, lengthening their sleep duration may be helpful to enhance the grip strength. This result has implications for improving their health by targeting better performance in specific physical functions. Further studies of sleep duration and physical function among older adults should investigate the underlying mechanisms.

Keywords: sleep duration, grip strength, physical function, older adults

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Existing studies lack the adjustment with objectively measured physical activity and have inconsistent results while examining older adults' sleep duration-physical function relationships. The aim of this research was to investigate the relationships between objectively measured sleep duration and physical function in older adults.

Study Impact: Our results indicated sleep duration is positively associated with grip strength in older adults. Given that grip strength is an important indicator of geriatric syndrome, the findings may suggest that strategies for lengthening sleep duration could be effective for maintaining healthy aging.

INTRODUCTION

The global life expectancy at birth has increased significantly by 5.5 years from 2000 to 2016.[1] In addition, the number of people aged 60 years or older is estimated to reach 2 billion worldwide by 2050.[2] Successful aging, defined as not only the absence of disease or disability but also the continuity of a better cognitive and physical function,[3] therefore has become one of the important health issues. Physical function, one of the identifying characteristics of sarcopenia,[4] has been reported as negatively associated with age[4] as well as the risks of disability[5] and mortality.[6,7] The examination of modifiable behavioral factors that could delay the physical function decline in older adults may inform developing new strategies to promote successful aging.

Sleep is a routine behavior that plays a critical role in the human body's homeostasis.[8] Generally, the appropriate sleep duration for older adults is regarded as 7–8 hours per night, with a 1–2 hour time buffer.[9] Inappropriate sleep duration, such as short sleep duration, was associated with a greater decline in physical function than those sleeping an appropriate duration.[10,11] However, previous studies mostly used self-reported sleep duration that may result in recall bias, particularly for older adults. Studies measuring sleep duration objectively aimed at eliminating recall bias could provide more accurate estimates when investigating the relationships between sleep duration and physical functions.

Previous studies objectively assessing sleep duration targeting older adults showed inconsistent findings. For example, studies from the United States[12,13] showed that inappropriate sleep duration was associated with worse physical function in younger-old adults (≥ 65 years) after adjusting for reported physical activity. By contrast, a study from Japan found no associations between sleep duration and physical function in oldest-old adults (≥ 80 years) after adjusting for accelerometer-measured physical activity.[14] Given the different nature of physical activity adjustment, the lifestyle varied by age groups, and the cultural differences between West and Asia, we aimed to investigate the relationships between accelerometer-measured sleep duration and physical function in a younger-old Taiwanese population after adjusting for objective-measured physical activity.

METHODS

Participants

We recruited community-dwelling older adults aged ≥ 60 years from 28 neighborhoods in Taipei City, Taiwan. For inclusion, the participants needed to have the ability to walk independently without assistance. Each participant was asked to complete some questions in relation to their demographic and health-related factors (health status and depression), as the questions of health status and depression were commonly used,[15,16] and perform 5 on-site tests to assess their physical function outcomes. Afterward, they were asked to wear accelerometers for 7 consecutive days, with the exception of water activities such as bathing or swimming, and record their bedtimes and wakeup times in a sleep log. A total of 170 older adults completed the questionnaire and on-site tests, 22 of them declined to wear the accelerometer to measure their sleep duration. After excluding data with incomplete information on personal characteristics (n = 5) and those wearing an accelerometer with insufficient valid days (n = 22), the data from 121 participants were included in the analyses. Data were considered valid for any participant who wore the device for at least 600 minutes per day for at least 4 days, including 1 weekend day, during the 7-day period.[17] Signed consent forms from all participants were obtained prior to participation, and the study was approved by the Research Ethics Committee of the National Taiwan Normal University (REC number: 201711HM003).

Objectively measured sleep duration

To accurately measure nightly sleep duration, ActiGraph wGT3×-BT triaxial accelerometers (ActiGraph, LLC, Pensacola, FL) were utilized. All participants were asked to wear an accelerometer on the hip 24 hours per day for 7 consecutive days. A strong correlation has been shown between sleep duration assessed by polysomnography and hip-worn devices.[18] The participants were also asked to record their bedtimes and wakeup times in a sleep log.[18,19] These logs were used to crosscheck the data recorded by the accelerometers. ActiLife version 6.0 software (Pensacola, FL) was used to process the raw data, and all analyses were conducted with data using 60-second epochs[17] We used the Cole-Kripke algorithm that was previously validated with adult participants[20] for scoring sleep, and the mean sleep duration of valid days was calculated for each participant.

Physical function

Five physical functions were measured by performing on-site tests, as follows:

1. Grip strength: Grip strength was measured using a hydraulic hand dynamometer (Jamar Plus+ Digital 563213, Lafayette Instrument Company, Lafayette, IN). Participants adjusted their elbows to 90° and then exerted maximum effort using 1 hand per time on the hand dynamometer. The same motion would be conducted using both hands by turns.
2. Balance: We assessed balance performance using the 1-leg standing test with eyes open. On-site examiners timed the participants from the moment they lifted 1 leg off the floor until they put their down on the floor, with the maximum test time set at 60 seconds.[21]
3. Lower body strength: The 5-times chair stand test was used to measure the participants' lower body strength.[22] They were instructed to rise from a chair to a full standing position and then sit back down on the sitting position in a seated position as quickly as possible. The total time for 5 identical repetitions was recorded.
4. Basic mobility: We assessed basic mobility using the timed up and go test.[23] Participants were instructed to rise from a standard chair, walk 3 meters forward, turn around, and then walk back to the chair and sit down as soon as possible.
5. Gait speed: The 5-meter walk test was used to measure gait speed. Participants were instructed to walk 11 meters as fast as possible. The on-site examiners would record the time spent walking in the middle 5 meters for each participant as the beginning and final 3 meters were interrupted by acceleration and deceleration.

The best performance selected from three (1) and two (2-4) repetitive attempts with a one-minute gap between these attempts and the performance measured once (5) were used for the analyses.

Covariates

Demographic information and health-related factors were collected from self-rated questionnaires. We included the following covariates: age, sex, marital status (married or not), and education (tertiary education or not). Self-reported weight and height were used to calculate the body mass index, and the participants were divided into 2 groups as normal weight (18–24 kg/m^2) or being overweight (> 24 kg/m^2).[24] We used a 5-point scale (from extremely good to extremely bad) to assess overall health status and categorized the results as fair-good (extremely good, good, and fair) or poor (bad and extremely bad). We also asked the participants to report whether they have frequently experienced symptoms of depression.

The physical activity assessed by accelerometers was also included as the covariate in the models based on previous findings.[11,13] Furthermore, after considering that the associations

Table 1—Studied characteristics of participants by sex.

Categorical Variables	Overall (n = 121)		Men (n = 35)		Women (n = 86)		*P* Value
	n	%	n	%	n	%	
Sex							
Men	35	28.9%	-	-	-	-	
Women	86	71.1%	-	-	-	-	
Marital status							.001**
Married	80	66.1%	31	88.6%	49	57.0%	
Not married	41	33.9%	4	11.4%	37	43.0%	
Education							.292
Tertiary education	27	22.3%	10	28.6%	17	19.8%	
No tertiary education	94	77.7%	25	71.4%	69	80.2%	
Body mass index (kg/m^2)							.624
Normal weight (18–24)	63	52.1%	17	48.6%	46	53.5%	
Overweight (> 24)	58	47.9%	18	51.4%	40	46.5%	
Health status							.194
Fair-good	38	31.4%	14	40.0%	24	27.9%	
Poor	83	68.6%	21	60.0%	62	72.1%	
Depressed symptoms							.335
Yes	16	13.2%	3	8.6%	13	15.1%	
No	105	86.8%	32	91.4%	73	84.9%	
Continuous Variables (units)	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	***P* Value**
Age (year)	70.0	5.0	68.7	3.8	70.5	5.4	.046*
Monitor wearing time per day (hour)	15.4	1.4	15.0	1.8	15.5	1.1	.107
Sedentary behavior time per day (hour)	10.1	1.2	10.1	1.4	10.1	1.1	.750
Moderate-to-vigorous physical activity time per day (minute)	24.6	23.3	36.2	28.0	19.9	19.4	.003**
Sleep duration per day (hour)	7.0	1.0	7.0	1.1	7.1	1.0	.633
Grip strength: hand grip dynamometer (kg)	24.9	7.0	33.1	6.5	21.5	3.5	< .001**
Balance: 1-leg standing test (second)	36.8	23.2	40.5	23.4	35.2	23.0	.257
Gait speed: 5-m walk test (second)	3.0	0.8	2.9	1.1	3.1	0.7	.216
Basic mobility: timed up-and-go test (second)	7.1	2.1	7.1	2.9	7.1	1.8	.986
Lower body strength: 5-times chair stand (second)	7.5	2.6	7.6	2.2	7.5	2.7	.852

**P* value < .05; ***P* value < .01.

of sedentary behavior with sleep duration[25] and physical function[26,27] might confound the association in question, we also regarded accelerometer-measured sedentary behavior as a covariate in the models. The Troiano algorithm[28,29] in ActiLife software was used to identify physical activity (≥ 100 cpm) or sedentary behavior (< 100 cpm).[30]

Statistical analyses

Chi-squared tests for categorical variables and *t* tests for continuous variables were conducted to examine if there were any sex differences using IBM SPSS 23.0 software (SPSS Inc., IBM, Chicago, IL). Scatterplots of the measured sleep duration and physical function outcomes showed possible nonlinear associations. Therefore, we used generalized additive models to examine the associations in question to allow a higher degree of freedom not restricted to integer numbers compared to a quadratic regression model.[31] This model provides a smooth function of the exposure variable that allows flexible fits with relaxed assumptions of the nonlinear associations,[32] thereby providing a potentially better data fit than fully parametric models. The *mgcv* package of R software was used to implement the generalized additive model, and the analyses were executed in R version 3.5.0.

RESULTS

Participant characteristics

The results from 121 older adults (men: 28.9%; mean age: 70.0 ± 5.0 years) were analyzed. **Table 1** shows that men were younger (68.7 vs 70.5 years), had a higher proportion married (88.6% vs 57.0%), and spent more time on moderate-to-vigorous physical activity than women (36.2 vs 19.9 min/day). The sex differences were also found in grip strength (33.1 kg in men vs 21.5 kg in women) but not in other performances of physical function. Sleep duration was similar in men (7.0 ± 1.1 hours) and women (7.1 ± 1.0 hours).

Sleep duration and physical function in older adults

The generalized additive model revealed that there was no statistical evidence for associations in sleep duration with most of the physical function outcomes (*P* = .428–.904). The only exception was grip strength (*P* = .005) even after adjusting for all covariates (**Figure 1**). This model showed a linear association (F = 8.18; the degree of freedom = 1) between sleep duration and grip strength (**Figure 1**).

To make sure the associations between sleep duration and physical function were not confounded by body mass index,[33] the grip strength standardized to body mass index was transformed[34] to conducted the generalized additive model. After the adjustment of all covariates, the significant relationship between sleep duration and standardized grip strength still existed (*P* < .001).

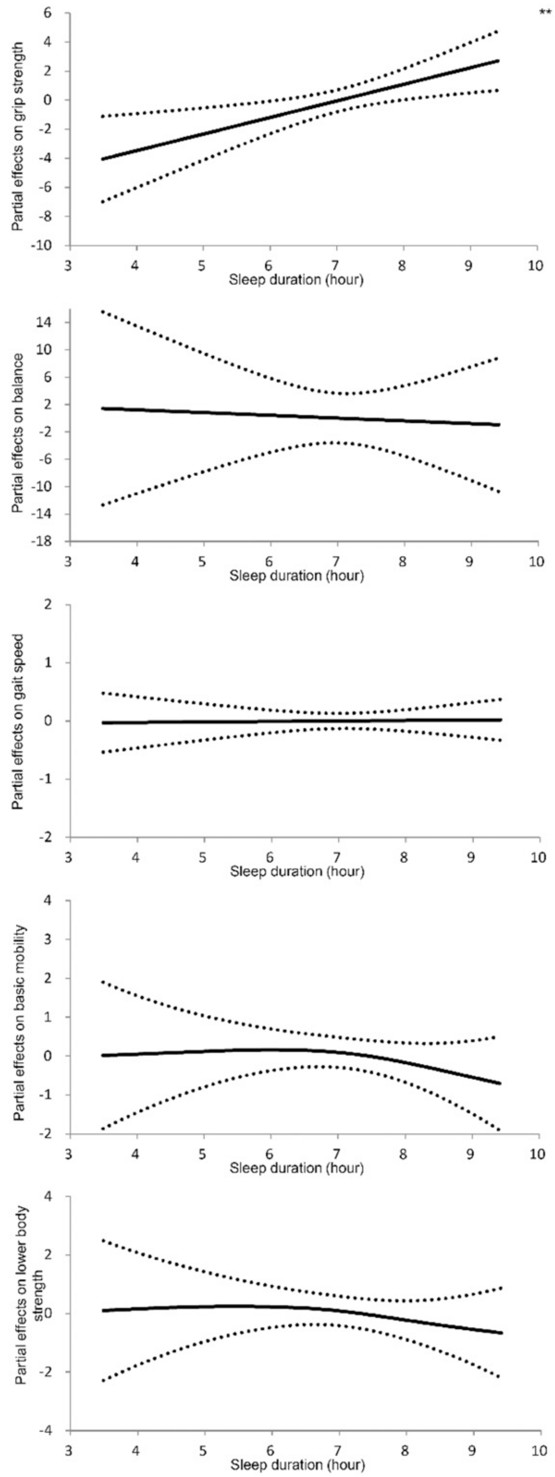
DISCUSSION

Our data showed that sleep duration among older adults had a positive association with grip strength performance but not with any other physical functions. These findings indicate that longer objectively measured sleep duration was associated with better grip strength performance in keeping with the previous prospective study.[35] The mechanisms underlying the association of sleep duration with grip strength remain unclear. Some possible explanations for the positive association between the 2 variables may be attributable to the detrimental effects of endocrine and immune systems derived from sleep deprivation (ie, short sleep duration). First, sleep deprivation is associated with insulin resistance[36,37] that has been proven to be associated with lower levels of muscle strength in older adults through the impairment of intracellular energy production[38] or the reduction in myocytes.[39] Second, sleep deprivation may result in increased secretion of proinflammatory cytokines[40] and cortisol.[37] Higher levels of these proinflammatory cytokines and cortisol may lead to muscle fiber atrophy and decrease[41] and muscle and protein degradation,[42] respectively. The loss of muscle mass may further cause a decline in muscle strength.[43]

Although previous findings have indicated that muscle strength may be decreased through the increased secretion of endocrine induced by sleep deprivation, our data showed that the association was observed only in grip strength and not in lower body strength. A possible explanation for this difference is that our data showed a smaller variance in lower body strength examined by 5-times chair stand (2.6 seconds) with a larger variance in grip strength (7.0 kg) examined by the hand grip dynamometer. The smaller variance in our participants' performance of lower body strength than grip strength may attenuate the associations observed. Future research is needed to further confirm these associations between sleep duration and different muscle strength measurements.

Our findings were inconsistent with previous findings that found long sleep duration to be associated with weaker grip strength compared with midrange sleep duration (ranged from 6 to 8 hours).[10,13] Cultural and lifestyle differences between Western and Asian nations may explain this inconsistency. For

Figure 1—Estimated dose-response relations between objectively measured sleep duration and physical function outcomes.



Models adjust for sex, age, marital status, education, depressed symptom, body mass index, health status, sedentary behavior, and moderate-to-vigorous physical activity. Dashed line: the range within one standard deviation. ***P* value < .01.

example, beverages like coffee, with higher concentrations of caffeine, are more popular in Western countries (eg, North America and Europe) than in Asia.[44] A recent review has indicated the consumption of caffeine typically leads to worse sleep quality.[45] Likewise, higher intake of junk food, which is high in calories, fat, processed carbohydrates but low in useful nutrients, in some Western countries may lead to less restorative sleep with more frequent arousals.[46] Furthermore, some specific physical activities such as tai chi are more common in older adults from Asian countries compared to those from Western ones. Tai chi exercise has been suggested to be associated with improved self-reported sleep quality,[47] which has significant correlations with the rate of microarousals.[48] As sleep efficiency and wake after sleep onset were associated with lower grip strength in older adults,[13,35] sleep quality in long sleepers may be better in Asian older adults compared to Western older adults because of lower intake of caffeine/junk food and specific physical activities. Future studies considering diverse sources of caffeine, such as coffee, tea, and energy drinks, dietary intake, and lifestyle factors are needed to confirm the underlying mechanism.

Other studies have shown no associations between sleep duration and grip strength.[12,14,49] Our sample showed a larger variance in grip strength performance (standard deviation = 7.0 kg) than the variance in previous studies (4.1 kg),[12] thus the performance of grip strength with a larger variation across samples may avoid the mitigation of the association. Furthermore, the inconsistency of associations between sleep duration and grip strength in different studies may be attributable to the interactive effects of age. One study showed a positive association of upper extremity function with hand dexterity in older adults,[50] and the reduced hand steadiness may cause unstable estimates of the associations in the previous study as their participants (mean age = 83.5 years) were older than ours (70.0 years).

Our study is among the few conducted within an Asian context related to the association between objectively assessed sleep duration and physical function among community-dwelling older adults. We measured the sleep duration of older adults using an actigraph to eliminate recall bias and increase the validity of the data. While the findings are important, some limitations in this study should be considered while interpreting the results. First, our small sample size may lead to less precise estimations of the associations in question, especially for those with long sleep duration. The findings may not be applicable outside the range of sleep duration. In addition, the convenience sample may not be generalized to the general population. Future research involving a representative population of older adults is suggested. Second, active older adults with health conditions may be more likely to participate in this study. However, our data on self-reported health status revealed a higher proportion of rather poor than good health; therefore, the effect of this limitation should be assumed to be limited. Third, covariates such as body mass index and health status may be affected by social desirability. Individuals tend to underestimate their weight and overestimate their height.[51] However, since trained research assistants met all participants, we confirmed that the reported data were not so different from physical appearance. Additionally, older adults may have a higher possibility to misperceive their health status, considering physical limitations as a part of the normal aging process.[52] Although this potential bias was unable to be ignored, better self-reported health status had significant correlations (absolute value of r ranged from .196 to .211; P values range from .02 to .03) with better performance of some objectively measured physical function (eg, grip strength and balance) in our data. Finally, this cross-sectional design could not infer causal relationships.

In conclusion, our data showed that there was a positive association between sleep duration and grip strength among older adults. Our findings have implications for healthy aging by delaying or mitigating the decline of physical function. Future research investigating objectively measured sleep duration with physical function among older adults is needed to explore the underlying mechanisms. The studies across long-term periods to examine the prevalence of older adults' physical function is also needed, and outcomes, such as grip strength, standardized to age or body mass index are suggested.

REFERENCES

1. World Health Organization. *World Health Statistics 2019: Monitoring Health for the SDGs*. World Health Organization; 2019. https://apps.who.int/iris/handle/10665/324835. Accessed November 12, 2019.
2. World Health Organization. *Ageing and Health*. 2018. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health. Accessed November 12, 2019.
3. Rowe JW, Kahn RL. Successful aging. *Gerontologist*. 1997;37(4):433–440.
4. World Health Organization. *World Report on Ageing and Health 2015*. 2015. https://www.who.int/ageing/publications/world-report-2015/en/.
5. den Ouden MEM, Schuurmans MJ, Arts IEMA, van der Schouw YT. Physical performance characteristics related to disability in older persons: a systematic review. *Maturitas*. 2011;69(3):208–219.
6. Wu Y, Wang W, Liu T, Zhang D. Association of grip strength with risk of all-cause mortality, cardiovascular diseases, and cancer in community-dwelling populations: a meta-analysis of prospective cohort studies. *J Am Med Dir Assoc*. 2017;18(6):551.e17–551.e35.
7. Veronese N, Stubbs B, Volpato S, et al. Association between gait speed with mortality, cardiovascular disease and cancer: a systematic review and meta-analysis of prospective cohort studies. *J Am Med Dir Assoc.* 2018;19(11):981–988.e7.
8. Czeisler CA. Duration, timing and quality of sleep are each vital for health, performance and safety. *Sleep Health*. 2015;1(1):5–8.
9. Hirshkowitz M, Whiton K, Albert SM, et al. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. *Sleep Health*. 2015;1(1):40–43.
10. Chen HC, Hsu NW, Chou P. The association between sleep duration and hand grip strength in community-dwelling older adults: The Yilan Study, Taiwan. *Sleep*. 2017;40(4):zsx021.
11. Stenholm S, Kronholm E, Bandinelli S, Guralnik JM, Ferrucci L. Self-reported sleep duration and time in bed as predictors of physical function decline: results from the InCHIANTI study. *Sleep*. 2011;34(11):1583–1593.
12. Goldman SE, Stone KL, Ancoli-Israel S, et al. Poor sleep is associated with poorer physical performance and greater functional limitations in older women. *Sleep*. 2007;30(10):1317–1324.
13. Dam TT, Ewing S, Ancoli-Israel S, Ensrud K, Redline S, Stone K. Association between sleep and physical function in older men: The MrOS Sleep Study. *J Am Geriatr Soc.* 2008;56(9):1665–1673.

14. Kim M, Yoshida H, Sasai H, Kojima N, Kim H. Association between objectively measured sleep quality and physical function among community-dwelling oldest old Japanese: A cross-sectional study. *Geriatr Gerontol Int.* 2015;15(8): 1040–1048.
15. Dowd JB, Zajacova A. Does the predictive power of self-rated health for subsequent mortality risk vary by socioeconomic status in the US? *Int J Epidemiol.* 2007;36(6):1214–1221.
16. Lachs MS, Feinstein AR, Cooney LM Jr, et al. A simple procedure for general screening for functional disability in elderly patients. *Ann Intern Med.* 1990;112(9): 699–706.
17. Migueles JH, Cadenas-Sanchez C, Ekelund U, et al. Accelerometer data collection and processing criteria to assess physical activity and other outcomes: a systematic review and practical considerations. *Sports Med.* 2017;47(9): 1821–1845.
18. Full KM, Kerr J, Grandner MA, et al. Validation of a physical activity accelerometer device worn on the hip and wrist against polysomnography. *Sleep Health.* 2018;4(2):209–216.
19. Shechter A, St-Onge MP. Delayed sleep timing is associated with low levels of free-living physical activity in normal sleeping adults. *Sleep Med.* 2014;15(12): 1586–1589.
20. Cole RJ, Kripke DF, Gruen W, Mullaney DJ, Gillin JC. Automatic sleep/wake identification from wrist activity. *Sleep*. 1992;15(5):461–469.
21. Muramoto A, Imagama S, Ito Z, et al. Threshold values of physical performance tests for locomotive syndrome. *J Orthop Sci.* 2013 18(4):618–626.
22. Buatois S, Miljkovic D, Manckoundia P, et al. Five times sit to stand test is a predictor of recurrent falls in healthy community-living subjects aged 65 and older. *J Am Geriatr Soc.* 2008;56(8):1575–1577.
23. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc.* 1991;39(2):142–148.
24. Ministry of Health and Welfare, Health Promotion Administration. New Guidelines on Daily Nutrition. https://www.hpa.gov.tw/File/Attach/6712/File_6253.pdf. Published 2018. Accessed January 22, 2021.
25. McClain JJ, Lewin DS, Laposky AD, Kahle L, Berrigan D. Associations between physical activity, sedentary time, sleep duration and daytime sleepiness in US adults. *Prev Med.* 2014;66:68–73.
26. Santos DA, Silva AM, Baptista F, et al. Sedentary behavior and physical activity are independently related to functional fitness in older adults. *Exp Gerontol.* 2012; 47(12):908–912.
27. Seguin R, Lamonte M, Tinker L, et al. Sedentary behavior and physical function decline in older women: findings from the Women's Health Initiative. *J Aging Res.* 2012;2012:271589.
28. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc.* 2008;40(1):181–188.
29. National Cancer Institute. SAS Programs for Analyzing NHANES 2003-2004 Accelerometer Data. 2007; https://epi.grants.cancer.gov/nhanes-pam/.
30. Troiano RP. Large-scale applications of accelerometers: new frontiers and new questions. *Med Sci Sports Exerc.* 2007;39(9):1501.
31. Jones K, Wrigley N. Generalized additive models, graphical diagnostics, and logistic regression. *Geogr Anal.* 1995;27(1):1–18.
32. Hastie T, Tibshirani R. Generalized additive models. *Stat Sci.* 1986;1(3): 297–310.
33. Sallinen J, Stenholm S, Rantanen T, Heliövaara M, Sainio P, Koskinen S. Hand-grip strength cut points to screen older persons at risk for mobility limitation. *J Am Geriatr Soc.* 2010;58(9):1721–1726.
34. McGrath R, Hackney KJ, Ratamess NA, Vincent BM, Clark BC, Kraemer WJ. Absolute and body mass index normalized handgrip strength percentiles by gender, ethnicity, and hand dominance in americans. *Adv Geriatr Med Res.* 2020; 2(1):e200005.
35. Spira AP, Covinsky K, Rebok GW, et al. Poor sleep quality and functional decline in older women. *J Am Geriatr Soc.* 2012;60(6):1092–1098.
36. Spiegel K, Knutson K, Leproult R, Tasali E, Van Cauter E. Sleep loss: a novel risk factor for insulin resistance and Type 2 diabetes. *J Appl Physiol (1985).* 2005;99(5): 2008–2019. 10.1152/japplphysiol.00660.2005
37. Lucassen EA, Rother KI, Cizza G. Interacting epidemics? Sleep curtailment, insulin resistance, and obesity. *Ann NY Acad Sci.* 2012;1264(1):110–134.
38. Abbatecola AM, Ferrucci L, Ceda G, et al. Insulin resistance and muscle strength in older persons. *J. Gerontol A Biol Sci Med Sci.* 2005;60(10):1278–1282.
39. Sayer AA, Syddall HE, Dennison EM, et al. Grip strength and the metabolic syndrome: findings from the Hertfordshire Cohort Study. *QJM*. 2007;100(11): 707–713.
40. Faraut B, Boudjeltia KZ, Vanhamme L, Kerkhofs M. Immune, inflammatory and cardiovascular consequences of sleep restriction and recovery. *Sleep Med Rev.* 2012;16(2):137–149.
41. Lee CE, McArdle A, Griffiths RD. The role of hormones, cytokines and heat shock proteins during age-related muscle loss. *Clin Nutr.* 2007;26(5):524–534.
42. Piovezan RD, Abucham J, Dos Santos RV, Mello MT, Tufik S, Poyares D. The impact of sleep on age-related sarcopenia: Possible connections and clinical implications. *Ageing Res Rev.* 2015;23(Pt B):210–220.
43. Singh T, Newman AB. Inflammatory markers in population studies of aging. *Ageing Res Rev.* 2011;10(3):319–329.
44. Reyes CM, Cornelis MC. Caffeine in the diet: country-level consumption and guidelines. *Nutrients*. 2018;10(11):E1772.
45. Clark I, Landolt HP. Coffee, caffeine, and sleep: A systematic review of epidemiological studies and randomized controlled trials. *Sleep Med Rev.* 2017; 31:70–78.
46. St-Onge MP, Roberts A, Shechter A, Choudhury AR. Fiber and saturated fat are associated with sleep arousals and slow wave sleep. *J Clin Sleep Med.* 2016; 12(1):19–24.
47. Du S, Dong J, Zhang H, et al. Taichi exercise for self-rated sleep quality in older people: a systematic review and meta-analysis. *Int J Nurs Stud.* 2015;52(1): 368–379.
48. Martynas Z, Vanda L, Ramune G, Raminta M, Osvaldas R. Arousals and macrostructure of sleep: importance of NREM stage 2 reconsidered. *Sleep Sci.* 2013;6(3):91–97.
49. Reyes S, Algarin C, Bunout D, Peirano P. Sleep/wake patterns and physical performance in older adults. *Aging Clin Exp Res.* 2013;25(2):175–181.
50. Liu CJ, Marie D, Fredrick A, Bertram J, Utley K, Fess EE. Predicting hand function in older adults: evaluations of grip strength, arm curl strength, and manual dexterity. *Aging Clin Exp Res.* 2017;29(4):753–760.
51. Nyholm M, Gullberg B, Merlo J, Lundqvist-Persson C, Råstam L, Lindblad U. The validity of obesity based on self-reported weight and height: Implications for population studies. *Obesity (Silver Spring)*. 2007;15(1):197–208.
52. Spuling SM, Wurm S, Tesch-Römer C, Huxhold O. Changing predictors of self-rated health: Disentangling age and cohort effects. *Psychol Aging*. 2015;30(2):462–474.

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DISCLOSURE STATEMENT

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