Effects of Sedentary Behavior, Physical Activity, Frequency of Protein Consumption, Lower Extremity Strength and Lean Mass on All-Cause Mortality

Paul D. Loprinzi* and Emily Frith
Department of Health, Exercise Science, and Recreation Management, The University of Mississippi, University, MS, USA

Background: No study has evaluated the potential independent and cumulative effects of physical activity, sedentary behavior, daily frequency of protein consumption, lean mass and muscular strength on mortality risk.

Methods: Data from the 1999-2002 NHANES were utilized (N = 1,079 adults 50-85 yr), with follow-up through 2011. Leg lean mass was estimated from DXA scans. Knee extensor strength was assessed using the Kin Com MP dynamometer. Physical activity and sedentary behavior were assessed via questionnaire, with the number of meals/day of ≥30 g of protein/meal assessed via a “multiple pass” 24-hour dietary interview. An index score was created (range = 0-5) indicating the number of these health characteristics each participant had.

Results: Only less sedentary behavior was independently associated with reduced mortality risk (HR\textsubscript{adjustment} = 0.46; 0.32-0.66). After adjustments, and compared to those with an index score of 0, those with an index score of 1, 2 and 3+, respectively, had a 34%, 49%, and 57% reduced risk of all-cause mortality.

Conclusion: While considering physical activity, sedentary behavior, daily protein frequency consumption, lean mass and muscular strength, only sedentary behavior was independently associated with mortality risk among older adults.

Key Words: Epidemiology, Muscle mass, Muscle strength, Protein distribution

INTRODUCTION

Concurrent engagement in multiple health behaviors, such as dietary behavior and regular physical activity, are favorably associated with lower extremity strength and lean mass [1], cardiovascular disease risk [2] and mortality risk [3]. Of interest in this paper is the potential independent and combined effects of five health-related parameters on mortality risk, with these including physical activity behavior, frequency of daily protein consumption, sedentary behavior, lower extremity strength, and lower extremity lean mass. Previous work has evaluated these parameters individually and demonstrated that physical activity behavior [4-9], frequency of daily protein consumption [10,11], sedentary behavior [12-19], lower extremity strength [4,20-22], and lower extremity lean mass [10,23] are associated with health outcomes, including mortality risk. We also acknowledge the potential interrelationships among these health parameters [10,24]. In concert, the aforementioned parameters are known to influence functional health, mobility, and body...
composition, but may also be independently associated with decreased mortality risk, even after adjusting for comorbidities [10,24-31]. What has yet to be evaluated, however, is whether these 5 health-related parameters are independently associated with mortality risk, or if indeed there are combined effects of these parameters on mortality risk. Thus, the purpose of this brief report was to evaluate the potential independent and combined effects of physical activity behavior, frequency of daily protein consumption, sedentary behavior, lower extremity strength, and lower extremity lean mass on all-cause mortality risk.

MATERIALS AND METHODS

1. Design and participants

Data were extracted from the 1999-2002 NHANES (only cycles with lower extremity muscle strength/lean mass data). Data from participants in these cycles were linked to death certificate data from the National Death Index. Person-months of follow-up were calculated from the date of the interview until date of death or censoring on December 31, 2011, whichever came first.

NHANES evaluates a representative sample of non-institutionalized U.S. civilians, selected by a complex, multi-stage probability design. NHANES is conducted by the National Center for Health Statistics (NCHS), and all procedures for data collection were approved by the NCHS ethics review board. Analyses were based on participants who provided data for the study variables and who did not have a physician-diagnosis of diabetes, coronary artery disease, musculoskeletal conditions (e.g., arthritis), on statin or anti-hypertensive medication, or consumed <600 or >4000 kcal/day. Notably, only those 50 and older were eligible for the muscle strength assessment. The analyzed sample included 1,079 consented adults (50-85 yr).

2. Peak knee extensor muscle strength

As described elsewhere [1,10], a Kin Com MP dynamometer (Chattanooga Group, Inc., Hixson, TN, USA) was used to assess voluntary peak isokinetic knee extensor strength in Newtons (at a speed of 60 degrees/second). A total of 6 measurements of muscle strength of the right quadriceps were taken: three warm-up trial measurements followed by 3 outcome measurements. If a participant completed 4-6 measures, the highest peak force was selected from trials 4 to 6; however, if a participant completed fewer than 4 measures, the highest peak force from the warm-up trials was selected. All values were gravity corrected for limb and lever arm weight [32]. Participants were defined as high strength if they were in the top quartile (i.e., >340 N) [21].

3. Leg lean mass

Leg lean mass was estimated using whole-body dual-energy x-ray absorptiometry (DXA) scans using the Hologic QDR 4500A fan beam x-ray bone densitometer (Hologic, Inc, Bedford, MA, USA) [1]. Lower extremity lean mass was calculated by summing the lower extremity lean mass (excluding bone mineral content) of the left and right legs. Notably, we included both left and right leg as the zero-order correlation of lean mass between the legs was, r = 0.988 (p < 0.0001). Participants were defined as high lean mass if they were in the top quartile (i.e., >17,545 g).

4. Frequency of protein consumption

A “multiple pass” 24-hour dietary interview format was used to collect detailed information about the participant’s dietary behavior [1]. This multiple pass format included asking participants to recall all foods and beverages consumed in a 24-hour period the day before the interview; report the time in which each food was eaten and what they would call the eating occasion for the food (e.g., breakfast); food probes were used to collect detailed information for each food reported; and the final reported foods were reviewed with the respondent in chronological order. Herein, we report the total daily consumption of protein (g), carbohydrate (g), total fat (g) and energy (kcal).

Similar to other work [1], of interest in this study was the meal frequency in which participants consumed adequate levels of dietary protein throughout the day. Thus, we evaluated the summed number of meals individuals consumed ≥30 g of protein per meal. This protein frequency variable could range from 0-6 (breakfast, brunch, lunch, snack, dinner, evening snack), but because of cell size considerations at greater protein frequency (i.e., number of meals/day ≥30 g of protein per meal), we recoded this pro-
tein frequency variable as <2 or 2+ meals/day ≥30 g of protein per meal.

5. Physical activity

The present study utilized self-reported physical activity data, as opposed to objectively-measured physical activity data, given that the objectively-measured physical activity data employed in NHANES was not collected until the 2003-2004 cycle; as stated previously, cycles 1999-2002 were evaluated herein because these are the only cycles with lower extremity strength data. As described elsewhere [33], participants were asked open-ended questions about participation in leisure-time physical activity over the past 30 days. Data was coded into 48 activities, including 16 sports-related activities, 14 exercise-related activities, and 18 recreational-related activities.

For each of the 48 activities where participants reported moderate or vigorous-intensity for the respective activity, they were asked to report the number of times they engaged in that activity over the past 30 days and the average duration they engaged in that activity. For each activity, Metabolic Equivalent of Task (MET)-min-month was calculated by multiplying the number of days, by the mean duration, by the respective MET level (MET-min-month = days × duration × MET level). The MET levels for each activity are provided elsewhere [34]. Participants were defined as meeting physical activity guidelines if they engaged in at least 2000 MET-min-month [33]. As described elsewhere, this physical activity assessment has demonstrated evidence of convergent validity by positively associating with accelerometer-assessed physical activity [33].

6. Sedentary time

Detailed previously [22], participants were asked, “Over the past 30 days, on a typical day how much time altogether did you spend sitting and watching TV or videos or using a computer outside of work?” Response options: less than 1 hr, 1 hr, 2 hrs, 3 hrs, 4 hrs, or 5+ hrs. In alignment with the other evaluated behaviors (physical activity and protein behavior) in the present study, this sedentary behavior variable was treated as a binary variable: participants were classified as ≤4 hrs/day of sedentary behavior or 5+ hrs/day, based on recent prospective research demonstrating that this level (5+ hrs/day) of sedentary behavior is associated with an increased mortality risk [35]. Notably, we also evaluated other thresholds (e.g., <2 vs. 2+ hrs/day), but results were unchanged, and thus, we chose to utilize the 5 hr/day threshold.

This screen-based sedentary behavior item has been shown to correlate with body mass index categories [36], which may, speculatively, provide some suggestive evidence of construct validity in that previous work has demonstrated a positive association between changes in sedentary behavior and body mass index [37]. Using data from the 2003-2006 NHANES (cycles with objective ‘overall’ sedentary data), we computed the correlation between this self-report screen-based sedentary behavior item and identical categories (hrs/day) of accelerometer-determined sedentary behavior (counts/min <100); a weak statistically significant association (r = 0.10, p < 0.0001) was observed, which is not unexpected as this self-report screen-based sedentary item only assessed non-occupational sedentary behavior, whereas accelerometry assesses overall daily sedentary behavior. This observed correlation is within the range (r = -0.19 to 0.80) of a review paper documenting the concurrent validity of television viewing time and other non-occupational sedentary behaviors (referent measures included heart rate monitoring, behavioral logs and accelerometry combined with behavioral logs) [38]; notably, only 3 of the evaluated studies from this review examined the validity of self-reported television viewing time and other non-occupational sedentary behaviors. This review, did, however, demonstrate moderate-to-high reliability of these measures (the majority of the ICC’s were >0.5).

7. Index variable

An index variable was created ranging from 0-5, indicating the number of positive characteristics the participant had. For example, a participant was given an index score of 5 if they: met physical activity guidelines (moderate-to-vigorous physical activity ≥2000 MET-min-month), had fewer than 5 hrs/day of leisure-time sedentary behavior, consumed 2+ meals/day ≥30 g of protein per meal, and were in the top quartile for both lower extremity lean mass and strength.
8. Statistical analyses

All analyses were performed in Stata (v. 12) and accounted for the complex survey design employed in NHANES. A Cox proportional hazard model was employed. Schoenfeld’s residuals were used to verify the proportional hazards assumption. There was no evidence of collinearity in the model as the highest correlation between two independent variables was, r = 0.57 (strength and lean mass). In the models, covariates included relative protein intake (g/kg), total daily carbohydrate (g), total daily fat (g), age (continuous; y), gender (male/female), race-ethnicity (Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, and other), mean arterial pressure (continuous; mmHg), and self-reported smoking status (current, former, never). Statistical significance was established as p < 0.05.

RESULTS

Participants, on average, were 60.7 years, with the sample equally distributed across gender (52.8% female). The percent of participants with 2+ meals/day of ≥30 g of protein per meal was 17.3%; the mean hrs/day of sedentary behavior was 2.3; mean MVPA MET-min/month was 4045.8; mean leg mass was 15011 g; and mean peak knee extensor strength was 376 N. During the median follow-up period of 124 months (IQR = 112-137), 227 participants died. In the sample, 127,719 person-months were observed with a mortality incidence of 1.77 deaths per 1,000 person-months.

Table 1 displays the results for the weighted Cox proportional hazard model. All five parameters were inversely associated with all-cause mortality risk, but only less sedentary behavior was statistically significantly associated with reduced mortality risk after adjustments (HR_{adjustment} = 0.46; 0.32-0.66; p < 0.001). Notably, in an unadjusted model (not shown in tabular format), only strength (HR = 0.52; 95% CI: 0.33-0.83; p = 0.009) and less sedentary behavior (HR = 0.39; 95% CI: 0.25-0.60; p < 0.001) were statistically significantly associated with reduced mortality risk.

With regard to the Index model, 182, 366, 312, 142, 64, and 13 participants had an index score of 0-5, respectively. As such, the index variable was recoded as 0, 1, 2, and 3+. After adjustments, and compared to those with an index score of 0, those with an index score of 1, 2 and 3, respectively, had a 34% (HR_{adjusted} = 0.66; 95% CI: 0.38-1.12; p = 0.12), 49% (HR_{adjusted} = 0.51; 95% CI: 0.27-0.95, p = 0.03), and 57% (HR_{adjusted} = 0.43; 95% CI: 0.22-0.86; p = 0.01) reduced risk of all-cause mortality. The Kaplan-Meier survival curve depicting probability of survival across these index scores is shown in Fig. 1.

Table 1. Weighted multivariable Cox proportional hazard analysis

| Independent Variable | Hazard Ratio | 95% CI         | p-value |
|----------------------|--------------|----------------|---------|
| Meets MVPA Guidelines vs. not | 0.80         | 0.54-1.17      | 0.24    |
| <5 hrs/day of sedentary behavior vs. 5+ hrs/day | 0.46         | 0.32-0.66      | <0.001  |
| 2+ meals/day 30 g of protein per meal vs. <2 meals/day | 0.99         | 0.53-1.86      | 0.99    |
| Top quartile for lean mass vs. not | 0.88         | 0.55-1.42      | 0.61    |
| Top quartile for muscular strength vs. not | 0.75         | 0.47-1.20      | 0.22    |

In the model, covariates included relative protein intake (g/kg), total daily carbohydrate (g), total daily fat (g), age (continuous; y), gender (male/female), race-ethnicity (Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, and other), mean arterial pressure (continuous; mmHg), and self-reported smoking status (current, former, never).
DISCUSSION

Previous research demonstrates that physical activity behavior [4-9], frequency of daily protein consumption [10,11], sedentary behavior [12-19], lower extremity strength [4,20-22], and lower extremity lean mass [10,23] are associated with health outcomes, including mortality risk. What has yet to be examined, however, is the unique contribution of each of these parameters within the same model on mortality risk. The major finding of the present study was that sedentary behavior, unlike the other 4 health-related parameters, was independently associated with mortality risk. However, there was some evidence (via the index model) that those with more of these health characteristics had a lower mortality risk when compared to those with fewer of these health characteristics.

A potential explanation for the distinct relationship between time spent participating in sedentary behavior and risk of all-cause mortality may be consequences of the modern office environment. Technological innovations advance workplace efficiency and productivity, but may impose substantial daily movement constraints. Many Americans are employed in sedentary professions, which present a difficult obstacle to accumulating adequate physical activity [39,40]. Research indicates office workers spend more than fifty percent of their workday sitting [41], and that, on workdays, employees may engage in seated tasks for nearly two hours longer than days spent outside of the office [42]. Further, inactivity on the job may contribute to over half of total weekly sedentary time [43]. Even among those meeting physical activity guidelines, active behaviors appear to be poor compensatory strategies against the detrimental impact of prolonged rest/leisure time [44-46]. Our results align with this hypothesis, as average time spent participating in physical activity was 4045.8 MVPA MET-min-month for this sample. Thus, although participants’ average activity level was well above the recommended 2000 MET-min-month [33], and was inversely associated with all-cause mortality risk, this relationship did not achieve statistical significance. Conversely, participants’ average sedentary time was 2.3 hours, well below the pre-determined mortality-risk threshold of >5 hrs/day [35], yet reduced sedentary time was a statistically significant independent predictor of all-cause mortality; the only significant predictor variable determined by our analysis.

Emerging work consistently demonstrates that sedentary behavior is independently associated with mortality risk [47]. For example, Biswas et al. [47] recently reviewed the literature via a meta-analysis evaluating outcomes for cardiovascular disease and diabetes (14 studies), cancer (14 studies), and all-cause mortality (13 studies). Higher levels of sedentary behavior were independently associated with increased all-cause mortality (HR, 1.24), cardiovascular disease mortality (HR, 1.18), cardiovascular disease incidence (HR, 1.14), cancer mortality (HR, 1.17), cancer incidence (HR, 1.13) and type 2 diabetes incidence (HR, 1.91). Based on these findings, coupled with the present study’s observation, minimizing prolonged sedentary behavior among older adults is of critical importance. Strategies to accomplish this have recently been discussed in the SOS-framework (Systems of Sedentary behaviors) [48].

Health promotion professionals should support physical activity initiatives aiming to increase opportunities for light physical activity in office environments [45]. Substituting prolonged seated behavior with brief movement breaks is suggested to combat adverse health risks linked with multimorbidity and mortality [49,50]. Such breaks are not expected to interfere with office productivity [51], and may even limit employee stress, anxiety, and depression [52], which arguably, would elevate workplace performance.

In conclusion, and while considering physical activity, sedentary behavior, daily protein frequency consumption, lean mass and muscular strength, only sedentary behavior was independently associated with mortality risk among older adults. However, there was some evidence that those with more of these health characteristics had a lower mortality risk. Despite the notable strengths of this study, which include the evaluation of a comprehensive mortality risk model, employing a national sample with a reasonable follow-up duration, and utilizing several objective measures, a limitation of the present study is the utilization of a subjective assessment of sedentary behavior. As such, future confirmatory work, particularly utilizing an objective measure of sedentary behavior, is warranted.
REFERENCES

1. Loprinzi PD, Loenneke JP, Hamilton DL. Leisure time sedentary behavior, physical activity and frequency of protein consumption on lower extremity strength and lean mass. *Eur J Clin Nutr* 2017;71:1399-404.

2. Loprinzi PD, Branscum A, Hanks J, Smit E. Healthy lifestyle characteristics and their joint association with cardiovascular disease biomarkers in US adults. *Mayo Clin Proc* 2016;91:432-42.

3. Loprinzi PD. Health behavior characteristics and all-cause mortality. *Prev Med Rep* 2016;3:276-8.

4. Loprinzi PD, Loenneke JP. Lower extremity muscular strength and leukocyte telomere length: Implications of muscular strength in attenuating age-related chronic disease. *J Phys Act Health* 2016;13:454-7.

5. Loprinzi PD. Combined effects of accelerometer-assessed physical activity and dietary behavior on all-cause mortality in a national prospective cohort study. *Int J Cardiol* 2015;201:258-9.

6. Loprinzi PD. Accelerometer-determined physical activity and mortality in a national prospective cohort study: Considerations by hearing sensitivities. *Am J Audiol* 2015;24:569-72.

7. Loprinzi PD. The effects of objectively-measured, free-living daily ambulatory movement on mortality in a national sample of adults with diabetes. *Physiol Behav* 2016;154:126-8.

8. Loprinzi PD. Accelerometer-determined physical activity and mortality in a national prospective cohort study of adults at high risk of a first atherosclerotic cardiovascular disease event. *Int J Cardiol* 2016;202:417-8.

9. Loprinzi PD, Sng E, Addob O. Physical activity and residual-specific mortality among adults in the United States. *Med Sci Sports Exerc* 2016;48:1730-6.

10. Loenneke JP, Loprinzi PD, Murphy CH, Phillips SM. Per meal dose and frequency of protein consumption is associated with lean mass and muscle performance. *Clin Nutr* 2016;35:1506-11.

11. Levine ME, Suarez JA, Brandhorst S, Balasubramanian P, Cheng CW, Madia F, Fontana L, Mirisola MG, Guevara-Aguirre J, Wan J, Passarino G, Kennedy BK, Wei M, Cohen P, Longo VD, et al. Low protein intake is associated with a major reduction in IGF-1, cancer, and overall mortality in the 65 and younger but not older population. *Cell Metab* 2014;19:407-17.

12. Edwards MK, Loprinzi PD. Effects of a sedentary behavior-inducing randomized controlled intervention on depression and mood profile in active young adults. *Mayo Clin Proc* 2016;91:984-98.

13. Edwards MK, Loprinzi PD. Experimentally increasing sedentary behavior results in increased anxiety in an active young adult population. *J Affect Disord* 2016;204:166-73.

14. Edwards MK, Loprinzi PD. Sedentary behavior & health-related quality of life among congestive heart failure patients. *Int J Cardiol* 2016;220:520-3.

15. Loprinzi PD. Sedentary behavior and predicted 10-yr risk for a first atherosclerotic cardiovascular disease (ASCVD) event using the pooled cohort risk equations among US adults. *Int J Cardiol* 2015;203:443-4.

16. Loprinzi PD. Sedentary behavior and medical multimorbidity. *Physiol Behav* 2015;151:385-7.

17. Loprinzi PD. Leisure-time screen-based sedentary behavior and leukocyte telomere length: Implications for a new leisure-time screen-based sedentary behavior mechanism. *Mayo Clin Proc* 2015;90:786-90.

18. Loprinzi PD, Kohli M. Effect of physical activity and sedentary behavior on serum prostate-specific antigen concentrations: results from the National Health and Nutrition Examination Survey (NHANES), 2003-2006. *Mayo Clin Proc* 2013;88:11-21.

19. Loprinzi PD, Sng E. The association of changes in sedentary behavior on changes in depression symptomology: Pilot study. *J Behav Health* 2016;5:140-4.

20. Buckner SL, Loenneke JP, Loprinzi PD. Lower extremity strength, systemic inflammation and all-cause mortality: Application to the “fat but fit” paradigm using cross-sectional and longitudinal designs. *Physiol Behav* 2015;149:199-202.

21. Dankel SJ, Loenneke JP, Loprinzi PD. Determining the importance of meeting muscle-strengthening activity guidelines: Is the behavior or the outcome of the behavior (strength) a more important determinant of all-cause mortality? *Mayo Clin Proc* 2016;91:166-74.

22. Loprinzi PD. Lower extremity muscular strength, sedentary behavior, and mortality. *Age (Dordr)* 2016;38:32.

23. Lee CG, Boyko EJ, Nielsen CM, Stefanick ML, Bauer DC, Hoffman AR, Dam TT, Lapidus JA, Cawthon PM, Ensrud KE, Orwoll ES, Osteoporotic Fractures in Men Study G. Mortality risk in older men associated with changes in weight, lean mass, and fat mass. *J Am Geriatr Soc* 2011;59:233-40.

24. Shad BJ, Wallis G, van Loon LJ, Thompson JL. Exercise prescription for the older population: The interactions between physical activity, sedentary time, and adequate nutrition in maintaining musculoskeletal health. *Maturitas* 2016;93:78-82.

25. Artero EG, Lee D-c, Ruiz JR, Sui X, Ortega FB, Church TS, Lavie CJ, Castillo MJ, Blair SN. A prospective study of muscular strength and all-cause mortality in men with hypertension. *J Am Coll Cardiol* 2011;57:1831-7.

26. Blair SN, Brodney S. Effects of physical inactivity and obesity on morbidity and mortality: current evidence and research issues. *Med Sci Sports Exerc* 1999;31: S646-S62.
27. Hairi NN, Cumming RG, Naganathan V, Handelsman DJ, Le Couteur DG, Creasey H, Waite LM, Seibel MJ, Sambrook PN. Loss of muscle strength, mass (sarcopenia), and quality (specific force) and its relationship with functional limitation and physical disability: the Concord Health and Ageing in Men Project. J Am Geriatr Soc 2010;58:2055-62.

28. Hamilton MT, Healy GN, Dunstan DW, Zderic TW, Owen N. Too little exercise and too much sitting: inactivity physiology and the need for new recommendations on sedentary behavior. Curr Cardiovasc Risk Rep 2008;2:292-8.

29. Minder CM, Shaya GE, Michos ED, Keenan TE, Blumenthal RS, Nasir K, Carvalho JA, Conceição RD, Santos RD, Blaha MJ. Relation between self-reported physical activity level, fitness, and cardiometabolic risk. Am J Cardiol 2014;113:637-43.

30. Ruiz JR, Sui X, Lobelo F, Lee D-c, Morrow JR, Jackson AS, Hébert JR, Matthews CE, Sjöström M, Blair SN. Association between bouted physical activity on multimorbidity. J Am Med 2007;12:337-42.

31. Loprinzi PD. Dose-response association of moderate-to-vigorous physical activity with cardiovascular biomarkers and all-cause mortality: Considerations by individual sports, exercise and recreational physical activities. Prev Med 2015;81:73-7.

32. Clark BK, Sugiyma T, Healy GN, Salmon J, Dunstan DW, Owen N. Validity and reliability of measures of television viewing time and other non-occupational sedentary behaviour of adults: a review. Obes Rev 2009;10:7-16.

33. Matthews CE, Chen KY, Freedson PS, Buchowski MS, Beech BM, Pate RR, Troiano RP. Amount of time spent in sedentary behaviors in the United States, 2003-2004. Am J Epidemiol 2008;167:875-81.

34. Ryan CG, Dall PM, Granat MH, Grant PM. Sitting patterns at work: objective measurement of adherence to current recommendations. Ergonomics 2011;54:531-8.

35. Ryan CG, Dall PM, Granat MH, Grant PM. Sitting patterns at work: objective measurement of adherence to current recommendations. Ergonomics 2011;54:531-8.

36. Biswas A, Rohal MI, Faulkner GE, Bajaj RR, Silver MA, Mitchell MS, Alter DA. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. Ann Intern Med 2015;162:123-32.

37. Chastin SF, De Craemer M, Lien N, Bernaards C, Buck C, Oostveen J, de Vries J, Donoghue G, Holdsworth M, Owen N, Brug J, Cardon G, Dedicap consortium ewg, consensus p. The SOS-framework (Systems of Sedentary behaviours): an international transdisciplinary consensus framework for the study of determinants, research priorities and policy on sedentary behaviour across the life course: a DEDIPAC-study. Int J Behav Nutr Phys Act 2016;13:83.

38. Biswas A, Rohal MI, Faulkner GE, Bajaj RR, Silver MA, Mitchell MS, Alter DA. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. Ann Intern Med 2015;162:123-32.

39. Chastin SF, De Craemer M, Lien N, Bernaards C, Buck C, Oppert JM, Nazare JA, Lakerveld J, O’Donoghue G, Holdsworth M, Owen N, Brug J, Cardon G, Dedicap consortium ewg, consensus p. The SOS-framework (Systems of Sedentary behaviours): an international transdisciplinary consensus framework for the study of determinants, research priorities and policy on sedentary behaviour across the life course: a DEDIPAC-study. Int J Behav Nutr Phys Act 2016;13:83.
and cycling computer workstations on keyboard and mouse performance. *Hum Factors* 2009;51:831-44.

52. Buckley JP, Hedge A, Yates T, Copeland RJ, Loosemore M, Hamer M, Bradley G, Dunstan DW. The sedentary office: an expert statement on the growing case for change towards better health and productivity. *Br J Sports Med* 2015;49:1357-62.