Obesity

# High Sitting Time or Obesity: Which Came First? Bidirectional Association in a Longitudinal Study of 31,787 Australian Adults

*Zeljko Pedisic*[1,2], *Anne Grunseit*[1], *Ding Ding*[1], *Josephine Y. Chau*[1], *Emily Banks*[3,4], *Emmanuel Stamatakis*[1,5,6,7], *Bin B. Jalaludin*[8] *and Adrian E. Bauman*[1]

**Objective:** Evidence on the direction of the association between sitting time and obesity is limited. The prospective associations between baseline total sitting time and subsequent changes in body mass index (BMI), and baseline BMI and subsequent changes in sitting time were examined.

**Methods:** BMI, from self-reported height and weight, and a single-item measure of sitting time were ascertained at two time points ($3.4 \pm 0.96$ years apart) in a prospective questionnaire-based cohort of 31,787 Australians aged 45–65 years without severe physical limitations.

**Results:** In a fully adjusted model, baseline obesity was associated with increased sitting time among all participants (adjusted odds ratio [aOR] = 1.20 [95% CI, 1.11-1.30]; $P < 0.001$) and in most subgroups. The association was significant among those who were sitting <4 hours/day (aOR = 1.24 [95% CI, 1.07-1.44]; $P = 0.004$) and 4–8 hours/day at baseline (aOR=1.18 [95% CI, 1.06-1.32]; $P = 0.003$), but not in the high sitting groups ($P = 0.111$ and 0.188 for 8–11 and ≥11 sitting hours/day, respectively). Nonsignificant and inconsistent results were observed for the association between baseline sitting time and subsequent change in BMI.

**Conclusions:** Our findings support the hypothesis that obesity may lead to a subsequent increase in total sitting time, but the association in the other direction is unclear.

*Obesity* (2014) **22**, 2126–2130. doi:10.1002/oby.20817

## Introduction

Moderate-to-vigorous-intensity physical activity (MVPA) may help to prevent weight gain and obesity (1). Prolonged sitting may be an independent health-risk factor (2) and have different associations with regional fat deposition than MVPA (3).

Television viewing time, a commonly investigated type of sedentary behaviour, seems to be predictive of subsequent weight gain (4-6). By contrast, total sedentary time tends to show nonsignificant (7,8) or inconsistent (9) associations with weight gain. These associations may be moderated by sex (4), employment status (10), baseline body mass index (BMI) (9), and MVPA (6).

It is also hypothesised that prior obesity predisposes to sedentary behavior. No significant prospective association between prior weight status and change in sitting time was found among young (8) or middle-aged women (9). Prior obesity was associated with higher subsequent TV viewing time among civil servants, but no association was found with occupational, non-TV leisure-time, or total sitting (7). Also, a significant relationship was found between baseline BMI and subsequent time spent inactive (11). Furthermore, no

[1] Prevention Research Collaboration, Sydney School of Public Health, The University of Sydney, Sydney, Australia. Correspondence: Dr Zeljko Pedisic (zeljko.pedisic@kif.hr) [2] Faculty of Kinesiology, University of Zagreb, Zagreb, Croatia [3] National Centre for Epidemiology and Population Health, Australian National University, Canberra, Australia [4] The Sax Institute, Sydney, Australia [5] Exercise Health and Performance Faculty Research Group, Faculty of Health Sciences, University of Sydney, Australia [6] Charles Perkins Centre, University of Sydney, Australia [7] Physical Activity Research Group (PARG), Department of Epidemiology and Public Health, Population Health Division, University College London, London, UK [8] School of Public Health and Community Medicine, The University of New South Wales, Sydney, Australia

**Funding agencies:** This study is a component of the National Health and Medical Research Council Strategic Award for Preventive Healthcare and Strengthening Australia's Social Economic Fabric (The SEEF Project; ID402810). EB is supported by the National Health and Medical Research Council of Australia.

**Disclosure:** The authors declare no competing interests.

**Author contributions:** AB, DD, and ZP conducted the literature search. AG analyzed the data. ZP generated the tables. All authors were involved in the data analysis planning, data interpretation, writing the paper and had final approval of the submitted and published versions.



**Received:** 30 September 2013; **Accepted:** 1 June 2014; **Published online 19 June 2014. doi:10.1002/oby.20817**

previous studies have taken into account possible ceiling effects in total sitting time, that is, the low likelihood of further increases in sitting time if it is already high at baseline.

Inconsistent findings underpin the need for clarification of the potentially bidirectional association between sedentary behavior and weight-related outcomes. This brief report examined prospective bidirectional associations between total sitting time and BMI in a large sample of middle-aged Australian adults, stratified by sex, employment status, baseline BMI and MVPA, to account for possible moderating effects, and by baseline sitting time, to account for potential ceiling effects.

# Methods

## Sampling and procedures

This study involved participants from the Social, Economic, and Environmental Factor study (SEEF), a follow-up of a sub-sample of the Sax Institute's 45 and Up Study. A total of 267,153 adults aged ≥45 years from New South Wales, Australia, joined the latter study between February 2006 and December 2009 (12). The first 100,000 respondents were invited to participate in SEEF, a mean ± SD of 3.3 ± 0.94 years after completing the baseline questionnaire (response rate: 64.4%). All participants completed consent forms at both surveys. The baseline data collection and SEEF were approved by the University of New South Wales Human Research Ethics Committee (reference: HREC 05035) and the University of Sydney Human Research Ethics Committee (reference: 10-2009/12187), respectively.

Our analyses were restricted to SEEF participants aged 45-65 years without severe physical limitations at baseline (Medical Outcome Score - Physical Functioning≥60) (13), who also reported no need for help with daily tasks because of long-term illness/disability ($n = 31,787$). We excluded those with disability because disability is related to both sedentary time and BMI (10) and could confound their relationship.

## Measures

Total sitting time was assessed using an open-ended question ("About how many hours in each 24 hour day do you usually spend sitting?"). Single-item assessment of total sitting time has demonstrated adequate measurement properties (14). BMI was calculated from participants' self-reported height and weight and categorized into: <18.5 (underweight); from ≥18.5 to <25 (normal weight); from ≥25 to <30 (overweight); and ≥30 kg/m$^2$ (obese). Previous 45 and Up Study research showed high agreement between BMI from measured and self-reported height and weight (15).

The following self-reported baseline measures were used as covariates: age; sex; education; employment status; previous doctor-diagnosis of chronic illnesses; psychological distress (16); single-item general health; MVPA assessed using six questions from the validated Active Australia Survey (categorized as <150; 150-300; ≥300 minutes/week) (17), and area-level socio-economic status (SEIFA) (based on the participant's residential postcode).

## Data analysis

Prospective associations between baseline total sitting time (independent variable) and change in BMI (dependent variable) were assessed using linear regression (Analysis 1), and between baseline BMI (independent variable) and change in total sitting time (dependent variable) using binary logistic regression (Analysis 2). The analyses were adjusted for covariates and baseline levels of outcome variables, and stratified by sex, employment status, MVPA, baseline BMI (Analysis 1), and baseline sitting (Analysis 2). Initially, two-level mixed models were used to take into account the SEIFA being measured at the postcode level. However, as the intraclass correlation coefficients (ICC) for both analyses were negligible (ICC < 0.001) and yielded minimal change compared with single level regressions, the latter analyses are reported.

*Analysis 1:* Sitting time (hours/day) was regressed on percent change in BMI per year between baseline and follow-up (%/year).

*Analysis 2:* BMI categories were regressed on change in sitting time (categorized as: increase [>0]; or "no change/reduction" [≤0]). Heterogeneity and linear trend were tested using the likelihood ratio chi-square test (complete vs. reduced model) and linear contrasts, respectively.

**TABLE 1** Socio-demographic characteristics of the sample and descriptive statistics for the exposure and outcome variables

| | *n* | % |
|---|---|---|
| Sex | | |
| Male | 13,516 | 42.5 |
| Female | 18,271 | 57.5 |
| Education level[a] | | |
| 1 | 7,546 | 23.9 |
| 2 | 13,624 | 43.2 |
| 3 | 10,370 | 32.9 |
| SEIFA[b] quintile | | |
| 1 (low) | 2,878 | 9.1 |
| 2 | 5,326 | 16.8 |
| 3 | 7,299 | 23.0 |
| 4 | 6,859 | 21.7 |
| 5 (high) | 9,315 | 29.4 |
| Employment status | | |
| Not working | 8,388 | 26.4 |
| Part time | 8,572 | 27.0 |
| Full time | 14,809 | 46.6 |
| Body mass index (BMI) | | |
| <18.5 | 296 | 1.0 |
| 18.5-25 | 11,798 | 39.3 |
| 25-30 | 11,925 | 39.8 |
| ≥30 | 5,973 | 19.9 |
| Total sitting time (hours/day) | | |
| <4 | 8,050 | 26.4 |
| 4-8 | 14,029 | 46.0 |
| 8-11 | 6,124 | 20.1 |
| ≥11 | 2,271 | 7.5 |
| Sitting time change[c] | | |
| No change or decreased (≤0) | 19,325 | 65.5 |
| Increased (>0) | 10,171 | 34.5 |

[a]Up to school or intermediate certificate (1); completed high school/leaving certificate/ trade apprenticeship/certificate/diploma (2); university degree or higher (3).
[b]Area-level socio-economic status.
[c]Change between baseline and follow-up.

**TABLE 2** Linear relationship[a] between total sitting time in hours/day (independent variable) and BMI[b] percent change per year between baseline and follow-up (dependent variable), stratified by sex, employment status, baseline BMI, and MVPA[c]

| | Intercept (95% CI)[d] | *b* (95% CI)[e] |
|---|---|---|
| **All participants (*n* = 26,493)** | 4.09 (3.61, 4.58) | 0.00 (−0.01, 0.00) |
| **Sex** | | |
| **Women (*n* = 14,883)** | 3.97 (3.35, 4.58) | 0.00 (−0.02, 0.01) |
| **Men (*n* = 11,610)** | 6.29 (5.52, 7.06) | −0.01 (−0.02, 0.00) |
| **Employment status** | | |
| **Not working (*n* = 6,814)** | 4.65 (3.71, 5.59) | 0.01 (−0.02, 0.03) |
| **Part time (*n* = 7,113)** | 3.70 (2.82, 4.57) | 0.00 (−0.02, 0.02) |
| **Full time (*n* = 12,566)** | 4.14 (3.42, 4.87) | −0.01 (−0.02, −0.00)* |
| **BMI[b] (kg/m$^2$)** | | |
| **<18.5 (*n* = 256)** | 17.53 (4.72, 30.35) | −0.08 (−0.40, 0.24) |
| **18.5–25 (*n* = 10,398)** | 2.31 (1.70, 2.91) | 0.00 (−0.02, 0.01) |
| **25–30 (*n* = 10,623)** | 1.38 (0.83, 1.94) | −0.01 (−0.02, 0.00) |
| **≥30 (*n* = 5,216)** | 0.63 (−0.34, 1.60) | 0.01 (−0.01, 0.03) |
| **MVPA[c] (minutes/week)** | | |
| **<150 (*n* = 4,204)** | 3.45 (2.23, 4.68) | −0.01 (−0.03, 0.02) |
| **150–300 (*n* = 4,589)** | 2.96 (1.78, 4.14) | −0.01 (−0.03, 0.01) |
| **≥300 (*n* = 17,700)** | 4.38 (3.79, 4.98) | 0.00 (−0.01, 0.01) |

[a]Adjusted for age, sex, educational level, area level socio-economic status, employment status, baseline BMI, chronic illnesses, risk of psychological distress, self-reported general health, and MVPA.
[b]Body mass index calculated from self-reported height and weight.
[c]Time spent in moderate- to vigorous-intensity physical activity.
[d]Intercept for BMI percent change per year between baseline and follow-up (%) and its 95% confidence interval.
[e]Unstandardized regression coefficient (slope) for total sitting time and its 95% confidence interval.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

## Results

From baseline to follow-up, 34.5% and 33.2% of respondents increased their sitting time and BMI, respectively (Table 1).

No significant relationships were found between baseline sitting time and subsequent change in BMI in the whole sample ($P = 0.292$) or in most strata ($P > 0.05$) (Table 2). The only significant relationship was found among full-time workers (unstandardized regression coefficient [$b$] = −0.01 [95% CI, −0.02-0.00]; $P = 0.038$), indicating slightly decreasing subsequent BMI with increasing baseline sitting time.

Being obese (versus normal weight) at baseline was associated with increased sitting time in the whole sample (adjusted odds ratio [aOR] = 1.20 [95% CI, 1.11-1.30]; $P < 0.001$) and in most strata (Table 3). We found a significant association between baseline BMI and change in total sitting time among those who were sitting <4 hours/day ($P$[heterogeneity] = 0.033; $P$[trend] = 0.006) and 4-8 hours/day at baseline ($P$[heterogeneity] = 0.034; $P$[trend] = 0.005), but not in the high sitting groups (8-11 and ≥11 hours/day).

The relationship of BMI to subsequent sitting time was stronger in nonworking than working individuals ($P$[interaction] = 0.038). Other interaction terms were not significant ($P > 0.05$).

## Discussion

Consistent with previous studies, we found no significant overall relationship between total sitting time and changes in BMI (7-9). The slight inverse relationship between these variables detected among full-time workers is an unexpected finding. To assess its robustness, we modelled BMI percent change categorized as decrease [≥3% decrease], stable [±3%, reference group], and increase [≥3% increase] (18) using multinomial logistic regression, and obtained mixed results; sitting ≥11 hours/day was associated with decreasing BMI in the whole sample, men, full-time workers, and overweight [but not obese] participants, and with increase in BMI among participants not in paid employment, but not overall or in other strata (data not shown). Given the small magnitude of the observed relationship among full-time workers in the initial analysis and inconsistent results in the sensitivity analysis, the findings require independent confirmation.

The significant association between baseline BMI and subsequent changes in total sitting time among all participants and in most strata is consistent with some, but not all previous findings (7-9). Our data support the hypothesis that people with a higher BMI have a greater propensity to become more sedentary (19). To account for possible ceiling effects, we stratified by baseline sitting time and found a significant association between obesity and increase in sitting time only among those who reported sitting <4 and 4-8 hours/day at baseline. The lack of significant association in other two sitting strata was expected *a priori*, because of the limited capacity for their high baseline total sitting time (8-11 or ≥11 hours/day) to increase further during the follow-up period. However, this might also be because of smaller sample sizes in the high sitting groups and/or possible residual confounding present in the whole sample and other strata, but absent in the high sitting groups.

**TABLE 3** Association between body mass index (independent variable) and longitudinal change in total sitting time (dependent variable),[a] stratified by sex, employment status, total sitting time at baseline, and MVPA[b]

| | BMI (kg/m$^2$)[c]; aOR (95% CI)[d] | | | | | |
|---|---|---|---|---|---|---|
| | <18.5 (*n* = 256) | 18.5–25 (*n* = 10,276) | 25–30 (*n* = 10,482) | ≥30 (*n* = 5,162) | *p*[e] | *p*[f] |
| All participants (*n* = 26,176) | 1.10 (0.83, 1.44) | 1.00 [ref] | 1.05 (0.99, 1.12) | 1.20 (1.11, 1.30)*** | <0.001 | <0.001 |
| Sex | | | | | | |
| Women (*n* = 14,707) | 1.04 (0.77, 1.41) | 1.00 [ref] | 1.06 (0.97, 1.15) | 1.24 (1.12, 1.38)*** | <0.001 | <0.001 |
| Men (*n* = 11,469) | 1.44 (0.76, 2.72) | 1.00 [ref] | 1.04 (0.94, 1.15) | 1.14 (1.00, 1.29)* | 0.160 | 0.053 |
| Employment status | | | | | | |
| Not working (*n* = 6,711) | 0.98 (0.58, 1.65) | 1.00 [ref] | 1.06 (0.93, 1.20) | 1.40 (1.21, 1.63)*** | <0.001 | <0.001 |
| Part time (*n* = 7,053) | 1.25 (0.81, 1.92) | 1.00 [ref] | 1.00 (0.88, 1.12) | 1.23 (1.06, 1.44)** | 0.029 | 0.020 |
| Full time (*n* = 12,412) | 1.06 (0.65, 1.73) | 1.00 [ref] | 1.08 (0.98, 1.18) | 1.07 (0.95, 1.20) | 0.424 | 0.167 |
| Total sitting[g] (hours/day) | | | | | | |
| <4 (*n* = 6,758) | 0.91 (0.57-1.45) | 1.00 [ref] | 1.05 (0.94-1.17) | 1.24 (1.07-1.44)** | 0.033 | 0.006 |
| 4–8 (*n* = 12,008) | 1.08 (0.74-1.58) | 1.00 [ref] | 1.05 (0.96-1.15) | 1.18 (1.06-1.32)** | 0.034 | 0.005 |
| 8–11 (*n* = 5,385) | 1.66 (0.82-3.36) | 1.00 [ref] | 1.03 (0.87-1.21) | 1.17 (0.96-1.43) | 0.215 | 0.145 |
| ≥11 (*n* = 2,025) | 2.35 (0.49-11.20) | 1.00 [ref] | 1.25 (0.86-1.83) | 1.35 (0.86-2.10) | 0.424 | 0.160 |
| MVPA[b] (minutes/week) | | | | | | |
| <150 (*n* = 4,159) | 1.08 (0.56, 2.09) | 1.00 [ref] | 1.05 (0.89, 1.25) | 1.21 (1.01, 1.46)* | 0.223 | 0.061 |
| 150–300 (*n* = 4,554) | 0.68 (0.30, 1.55) | 1.00 [ref] | 1.05 (0.90, 1.22) | 1.14 (0.95, 1.37) | 0.398 | 0.179 |
| ≥300 (*n* = 17,463) | 1.18 (0.85, 1.63) | 1.00 [ref] | 1.06 (0.98, 1.14) | 1.21 (1.10, 1.34)*** | 0.002 | <0.001 |

[a]Difference in total sitting time between follow up and baseline categorized as: (0) ≤0 (decrease/no change); and (1) >0 (increase).
[b]Time spent in moderate- to vigorous-intensity physical activity.
[c]Baseline body mass index calculated from self-reported height and weight (normal BMI [18–25 kg/m$^2$] was used as the reference category).
[d]Odds ratio adjusted for age, sex, educational level, area level socio-economic status, employment status, baseline total sitting time, chronic illnesses, risk of psychological distress, self-reported general health, and time spent in moderate- to vigorous-intensity physical activity and its 95% confidence interval.
[e]*p*-value based on the likelihood ratio chi-square test of heterogeneity (complete vs. reduced model).
[f]*p*-value based on the chi-square test for linear trend (linear contrasts method).
[g]Total time spent sitting at baseline.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Strengths of our study include a large population-based sample, adjusting for numerous potential confounders, and stratification by sitting time in Analysis 2.

Limitations include: (1) not adjusting for dietary habits, (2) using self-report data on BMI and sitting time, and, therefore, possible underreporting among specific subgroups (e.g., overweight or obese people), (3) relatively short follow-up period, and (4) the single-item measure of sitting-time that precluded testing for domain-specific effects.

To conclude, our findings do not support the hypothesis that prolonged sitting time is predictive of weight gain, but do support the reverse causality hypothesis that obesity may lead to subsequent increases in total sitting time. O

## Acknowledgments

The authors thank the Sax Institute for permission to use the 45 and Up Study baseline questionnaire data. The 45 and Up Study is managed by the Sax Institute in collaboration with major partner Cancer Council NSW; and partners the Heart Foundation (NSW Division); NSW Ministry of Health; beyondblue; Ageing, Disability and Home Care, NSW Family and Community Services; the Australian Red Cross Blood Service; and UnitingCare Ageing. We thank the thousands of Australians for their ongoing participation and generous contributions to the 45 and Up Study.



## References

1. Reiner M, Niermann C, Jekauc D, Woll A. Long-term health benefits of physical activity - A systematic review of longitudinal studies. *BMC Public Health* 2013;13.
2. Dunstan DW, Howard B, Healy GN, Owen N. Too much sitting—A health hazard. *Diabetes Res Clin Pract* 2012;97: 368-376.
3. Larsen BA, Allison MA, Kang E, et al. Associations of physical activity and sedentary behavior with regional fat deposition. *Med Sci Sports Exerc* 2014;46:520-528.
4. Parsons TJ, Manor O, Power C. Television viewing and obesity: A prospective study in the 1958 British birth cohort. *Eur J Clin Nutr* 2008;62:1355-1363.
5. Ding D, Sugiyama T, Owen N. Habitual active transport, TV viewing and weight gain: A four year follow-up study. *Prev Med* 2012;54:201-204.
6. Wijndaele K, Lynch BM, Owen N, Dunstan DW, Sharp S, Aitken JF. Television viewing time and weight gain in colorectal cancer survivors: A prospective population-based study. *Cancer Causes Control* 2009;20:1355-1362.
7. Pulsford RM, Stamatakis E, Britton AR, Brunner EJ, Hillsdon MM. Sitting behavior and obesity: Evidence from the Whitehall II study. *Am J Prev Med* 2013;44:132-138.
8. De Cocker KA, van Uffelen JGZ, Brown WJ. Associations between sitting time and weight in young adult Australian women. *Prev Med* 2010;51:361-367.
9. van Uffelen JGZ, Watson MJ, Dobson AJ, Brown WJ. Sitting time is associated with weight, but not with weight gain in mid-aged Australian women. *Obesity* 2010;18:1788-1794.

10. Banks E, Jorm L, Rogers K, Clements M, Bauman A. Screen-time, obesity, ageing and disability: Findings from 91 266 participants in the 45 and Up Study. *Public Health Nutr* 2011;14:34-43.

11. Ekelund U, Brage S, Besson H, Sharp S, Wareham NJ. Time spent being sedentary and weight gain in healthy adults: reverse or bidirectional causality? *Am J Clin Nutr* 2008;88:612-617.

12. Banks E. Cohort profile: The 45 and up study. *Int J Epidemiol* 2008;37:941-947.

13. George ES, Jorm L, Kolt GS, Bambrick H, Lujic S. Physical activity and psychological distress in older men: Findings from the New South Wales 45 and Up Study. *J Aging Phys Act* 2012;20:300-316.

14. Healy GN, Clark BK, Winkler EAH, Gardiner PA, Brown WJ, Matthews CE. Measurement of adults' sedentary time in population-based studies. *Am J Prev Med* 2011;41:216-227.

15. Ng SP, Korda R, Clements M, et al. Validity of self-reported height and weight and derived body mass index in middle-aged and elderly individuals in Australia. *Aust N Z J Public Health* 2011;35:557-563.

16. Kessler RC, Andrews G, Colpe LJ, et al. Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychol Med* 2002;32:959-976.

17. Australian Institute of Health and Welfare. The Active Australia Survey: A Guide and Manual for Implementation, Analysis and Reporting. AIHW: Canberra, 2003.

18. Stevens J, Truesdale KP, McClain JE, Cai J. The definition of weight maintenance. *Int J Obes* 2006;30:391-399.

19. Levine JA, Lanningham-Foster LM, McCrady SK, et al. Interindividual variation in posture allocation: Possible role in human obesity. *Science* 2005;307:584-586.