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Sitting time is associated with weight, but not with weight gain in mid-aged Australian women

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ABSTRACT

The aim of this study was to examine the associations between sitting time, weight and weight gain in Australian women born in 1946-1951. Data were from 8233 women who completed surveys for the Australian Longitudinal Study on Women's Health in 2001, 2004, and 2007. Associations between sitting time and weight, and between sitting time and weight change in each three year period were examined using repeated measures modeling. The associations between weight and change in sitting time were also examined. Analyses were stratified for BMI categories: normal weight (18.5 ≤BMI< 25), overweight (25≤BMI<30), and obese (BMI≥30). In cross-sectional models, each additional hour of sitting time was associated with 110 grams (95%CI: 40-180) and 260 grams (95%CI: 140-380) additional weight in overweight and obese women respectively (fully adjusted model). In prospective analyses sitting time was not consistently associated with weight change, after adjustment for other variables, and weight was not associated with change in sitting time over successive three year periods. In conclusion, although the cross-sectional associations between sitting time and weight were evident in overweight and obese women, there was no consistent association between sitting time and weight gain. A potential explanation is that prospective associations may only be apparent over longer periods of time. These results do not support a role for reducing sitting time as a short-term means of weight control in mid-aged women.

INTRODUCTION

As in many developed countries, there is currently an epidemic of overweight and obesity in Australia. In Australian women, the prevalence of overweight and obesity is highest in women aged 55 to 64 years; 61 percent of this age group had a body mass index (BMI) greater than 25 kg/m^2 in 2007(1), and mid-aged women are continuing to gain weight at a rate of about 0.5 kilograms per year(2;3). As excess weight is positively associated with metabolic and cardiovascular disease in this population(4;5), it is important to prevent weight gain.

Weight gain is generally caused by an imbalance between energy intake and energy expenditure. Although the relationships between physical activity and weight gain are well studied(6), few studies have focused specifically on the relationships between sitting time and weight or weight gain in mid-aged women. Several studies have shown cross-sectional associations between time spent watching TV and overweight or obesity in adult women(7-10), and between sitting time and BMI(11).

Prospective studies assessing causation, and the direction of the relationship between sitting time and weight in mid-aged women are scarce. In a six year follow-up study to the US Nurses cohort study, Hu et al. observed a positive association between television watching and obesity risk in 50,277 mid-aged women with an initial BMI below 30 kg/m^2(12). In 2007, Blanck et al. also reported that the odds of gaining more than 4.5 kilograms over seven years were higher in mid-aged US women who sat for more than six hours per day in leisure time (OR = 1.47), than in women who sat for less than three hours (OR = 1.00) (13). This finding was, however, true only for the 11,540 women with a BMI less than 25 kg/m^2 at baseline. These findings suggest that there may be differences in the relationship between sitting time and weight gain according to BMI category.

Earlier results from the Australian Longitudinal Study on Women's Health found a positive relationship between sitting time in 2001 and odds of gaining more than five kilograms over the previous five years, in 8,071 women aged 45-50 years in 1996(2). From these results, the direction of the relationship between sitting time and weight gain could not be established. The aim of the present study was therefore to examine cross-sectional associations between sitting time and weight, and prospective associations between sitting time and weight gain in normal weight, overweight and obese mid-aged women over a six year period. It was hypothesized that sitting time would be positively associated with weight and weight gain in women in these three BMI categories. To address the issue of reverse causality, associations between weight and subsequent changes in sitting time were also examined.

METHODS

Australian Longitudinal Study on Women's Health (ALSWH)

The ALSWH is a prospective study of factors affecting the health and well-being of three cohorts of Australian women born in 1973-1978, 1946-1951 and 1921-1926(14). The women were randomly selected from the national Medicare health insurance database, which includes all Australian citizens and permanent residents(15). Women from rural and remote areas were intentionally over-sampled. Since 1996 surveys have been administered to each cohort every 3 years on a rolling basis. More details about the study can be found at www.alswh.org.au. The study is approved by the University of Queensland and the University of Newcastle Ethics Committees, and informed consent is received from all respondents.

Participants and surveys

In 1996, 14,099 women born in 1946-1951 (ages 45-50 years) completed the first survey. The women were broadly representative of the general population in their age groups(14);

although there was over-representation of Australian born, employed and university-educated women(15). Data for this paper were from women in this cohort who responded to the third, fourth, and fifth surveys in 2001 (n=11,226), 2004 (n=10,905) and 2007 (n=10,638). Of the 9,427 women who responded to all three surveys, 1,074 were excluded for the following reasons: 581 had missing data for weight or height in 2001; 475 had missing data for weight in 2004 or 2007; and 18 were excluded because they indicated that they were "limited a lot" in walking 100 meters in all three surveys. Women were also excluded from analysis for any survey in which they responded that they were limited in walking 100 meters. Thus there were 8,353 women with data at one, two or three surveys. Additionally, 120 women who had a BMI less than 18.5 in 2001 were also excluded, leaving 8,233 women with a total of 24,386 observations.

Measures

Body mass index (BMI, kg/m^2) was calculated using self-reported weight and height. The analysis was stratified for BMI category in 2001, as defined by the World Health Organization classification (16): underweight, BMI<18.5 (n=120, excluded from analysis), normal weight, 18.5≤BMI<25 (n=3,625), overweight, 25≤BMI<30 (n=2,712), and obese, BMI≥30 (n=1,896).

Main outcome variables

Two main outcome variables were used in these analyses: weight (in 2001, 2004, and 2007) and percentage weight change over three years (between 2001-2004, and 2004-2007). For each woman, percentage weight change was calculated by the formula [(W2 - W1) / W1] * 100, where W1 and W2 were weights at successive surveys.

Main explanatory variable

Sitting time was assessed using the following question: how many hours each day do you typically spend sitting down while doing things like visiting friends, driving, reading, watching television or working at a desk or computer: a) on a usual weekday; and b) on a usual

weekend day? Reported weekday sitting time exceeded 24 hours per day for 3% of the women and more than 80 percent of these out of range values were divisible by five. As the sitting questions were preceded by the Active Australia questions (see description below), which asked about physical activity in hours per week, it was assumed that these women had reported sitting time over five weekdays instead of one day and these values were therefore divided by five. Values for weekend-day sitting which exceeded 24 hours and were divisible by two were divided by two. All values which, after cleaning, exceeded 16 hours were set to missing. Similar generic sitting time questions are used in the International Physical Activity Questionaire, which, in women, have been shown to have good reliability and moderate criterion validity against accelerometers (< 100 counts per minute) (17). Mean sitting time in hours per day was calculated for the analysis in this paper as [(weekday sitting x 5 + weekend day sitting x 2)/7].

Other explanatory variables

The following variables were selected for inclusion in the adjusted model because they were statistically significantly associated with weight, or with sitting time and weight, in univariate cross-sectional models. These variables were also included as covariates in the prospective models. Sociodemographic variables included country of birth, area of residence, highest level of education, hours worked per week, and marital status.

Biological variables included depression (Center for Epidemiological Studies depression questionnaire (CES-D 10)(18)) (women with scores ≥ 10 were classified as 'depressed') and number of chronic diseases. Number of chronic diseases was categorized as none, one, two, or three or more, from a list of 15 conditions that women reported they had been told they had by a doctor in the previous three years.

Behavioral variables included physical activity, energy intake, smoking and alcohol status. Survey items to assess physical activity were based on the Active Australia survey and have

acceptable measurement characteristics(19). The frequency and duration in the previous week of time spent walking briskly and in moderate and vigorous intensity leisure-time physical activities (MLTPA and VLTPA) were reported. A physical activity score was calculated as the sum of the products of total time in each of the three categories and the metabolic equivalent value (MET) assigned to each category as reported previously (20): (walking minutes*3.0 METs) + (MLTPA*4.0 METs) + (VLTPA*7.5 METs). Physical activity scores were categorized as none (<40), very low (40-300), low (300-600), moderate (600-1200) or high (≥1200). Energy intake (EI) was assessed in 2001 using the Cancer Council of Victoria food frequency questionnaire(21). This a validated instrument that assesses usual consumption of 74 foods and 6 alcoholic beverage items over the past twelve months(21). Total EI was computed using software developed by the Cancer Council of Victoria, based on the NUTTAB95 nutrient composition data for Australia(22). Quintiles of EI were created and rounded to the nearest hundred kilojoules per day: very low (≤4800), low (>4800-5800), moderate (>5800-6800), high (>6800-8300), and very high (>8300). Smoking was categorized as: never smoked; ex smoker (quit before survey 3 in 2001); and current smoker. For alcohol status, women were categorized as: non-drinker; rarely drinker (<1 drink/week)*;* low risk drinker (1-14 drinks/week); or risky drinker (≥15 drinks/week).

Statistical Analysis

Comparisons of women across BMI groups were performed using chi-squared tests for categorical variables and analysis of variance for continuous variables. The effect of sitting time on weight and percentage weight change in the subsequent three years was estimated using repeated measures regression models. Three models were examined for each outcome: 1) a ‘simple model’ which included sitting time and year (survey) as explanatory variables; 2) an ‘energy balance model’ which included the variables in the simple model plus physical activity and energy intake; and 3) an adjusted model that also included the other sociodemographic, biological and behavioral variables as described above. The analyses were stratified by BMI category in 2001. To address the issue of reverse causality a model

was fitted, with weight (in 2001, 2004) as the explanatory variable and subsequent change in sitting time (2001-2004 and 2004-2007) as the outcome. All statistical analyses were conducted using SAS Software, Version 9.1.3 SP4 of the SAS System for Windows (Copyright © 2002-2003 SAS Institute Inc., Cary, NC, USA). The MIXED procedure in SAS was used for the repeated measures regression models with random effects for participants and an unstructured covariance matrix.

RESULTS

Data from 8233 women were included in the analyses. In 2001, 3625 (44 %) were in the normal weight range, 2712 (33 %) were overweight and 1896 (23 %) were obese. The sociodemographic, biological and behavioral characteristics of women in each BMI category are shown in Table 1. Mean sitting time increased with BMI-category and was consistently highest in obese women and lowest in normal weight women ($p<0.0001$). Percentage weight change also differed significantly between the three BMI-groups ($p<0.0002$). Normal weight and overweight women gained weight during the six year follow up, but percentage weight gain between 2004 and 2007 was almost half that seen in the 2001-2004 period (see Table 1). Average percentage weight change was much smaller among obese women than among normal weight and overweight women in both periods.

Sitting time was statistically significantly associated with weight in overweight and obese women. Each additional hour of sitting time was associated with 110 grams (95% CI: 40-180) and 260 grams (95%CI: 140-380) more weight for overweight and obese women respectively (Table 2, adjusted model). The interaction term between sitting time and survey was not statistically significant, suggesting that the association between sitting time and weight did not change over the three surveys.

Sitting time was statistically significantly and positively associated with percentage weight change from 2001 to 2004 and from 2004 to 2007 in normal weight women, but negatively

associated in overweight women (Table 3, univariate and energy balance models). For both the normal weight and overweight women, the association between sitting time and weight change did not remain statistically significant in the fully adjusted model. Among the obese women there were no statistically significant associations between sitting time and weight change. There was no evidence of an association between weight in 2001 or 2004 and change in sitting time (hrs/day) between 2001-2004 and 2004-2007 (Table 4).

DISCUSSION

This study examined the associations between sitting time and weight, and sitting time and weight gain, over successive three year periods in Australian women aged 45 to 50 years in 1996. Our first hypothesis, that sitting time would be associated with weight, was supported for overweight and obese women. This association was largely unchanged after adjustment for energy balance, behavioral and sociodemographic variables. There was no consistent association between sitting time and percentage weight gain. Therefore, the results did not support our second hypothesis that sitting time would be associated with weight gain.

The main weakness of this study was that the data were self-reported. It is therefore likely that some misclassification in the BMI categories occurred, because BMI calculated from measured weight and height is generally higher than BMI calculated using self-reported measures(23). However, provided the underestimation in self-reported weight was consistent over time, it is not likely that percentage weight change would be markedly affected. Sitting time was also self-reported and the validity of the sitting time questions used in this study has not been extensively examined. The questions were similar to those used in the International Physical Activity Questionnaire which have been shown to have good reliability and moderate validity (17). To date, most prospective cohort studies have relied on self-reported measures to examine relationships between both physical activity and sitting time with weight gain and other health outcomes(12;13). Objective measures, such as accelerometers, have recently been included in some large population-based surveillance studies. However, they

have not yet been included in large prospective cohort studies, mostly due to logistic and financial constraints.

Particular strengths of this study were the inclusion of a large number of women who were randomly selected from a population database(14), use of continuous variables for sitting time and weight gain, and the use of longitudinal analysis techniques that allow full use of repeated measurements taking into account variability within subjects over time.

In contrast to previous studies using cross-sectional data, this study used data collected at three time points over six years to examine the association between sitting time and weight gain. The results from this sophisticated analysis confirm the previously observed statistically significant association between sitting time and weight(11), but only in overweight and obese women. The weight associated with each additional hour of sitting time was 110 and 260 grams per hour of sitting time in overweight and obese women respectively. These estimates are greater than those reported in a previous study of almost 8000 women from 15 European countries(11) which estimated that each additional hour of leisure time sitting was associated with 65 additional grams of weight for a typical woman. One potential explanation is that the European researchers reported average weight for all women, regardless of BMI category. Other reasons may be that the sitting time measure included only leisure time sitting (whereas our estimate was based on all sitting time, including for leisure, transport and work), and the age range of the participants (mid aged women in our study and women aged 15+ in the European study). However, together with other evidence of a cross-sectional association between sitting time and BMI, or sitting time and being overweight or obese(7-11), the results of the present study suggest that there is a clear positive relationship between sitting time and weight, at least in overweight and obese women.

Our prospective data did not show consistent associations between sitting time and weight gain in women aged 45 to 50 years in any of the BMI categories. The results of the present

study contrast with those of reported by Blanck et al. who found a positive association between recreational sitting time (categorized into tertiles) and substantial weight gain over seven years, but only in women with a BMI below 25 (adjusted for age, physical activity, education, smoking, hormone therapy use, energy intake) (13). However, these researchers categorized weight gain and compared the odds for gaining more or less than 4.5 kilograms(13). Although they found that sitting time was associated with weight gain of more than 4.5 kg, they did not show an association between sitting time and a more moderate weight gain of 2.25 to 4 kilograms.

Explanations for the different findings could be that each study had different inclusion criteria and different domains of sitting time were assessed. Blanck et al. examined leisure time sitting only (defined as TV watching, reading, etc) (13). In the US Nurses Health Study, Hu et al. examined the association between sitting time and the risk of becoming overweight over four years (1992 to 1998); women who were already obese in 1992, or had reported being obese in earlier surveys since the start of the Nurses Health Study in 1976 were excluded(12). These researchers found that every two hour increase in TV watching was associated with a 23 percent (95% confidence interval: 17-30) increase in obesity risk(12). The association between 'sitting time at work, or away from home or driving', was, however, considerably weaker, with only a five percent (95% CI: 0-10) increased risk of developing obesity over six years. Previous researchers have suggested that the stronger association between TV watching and weight may be induced by a higher energy intake due to snacking, which in turn may be influenced by exposure to food advertising(24;25).

There are several possible reasons why there was a significant association with weight, but not with weight gain. The first is the possibility of reverse causation or bi-directional causality, which has been raised in previous studies(26-28). For example, in a study of almost 5,000 middle aged men and women, Mortensen et al. found that BMI was associated with increased risk of becoming sedentary (defined as the absence of physical activity) over 14

years(28). Ekelund et al. used heart rate monitors to measure sedentary time and physical activity levels in 393 mid-aged subjects; they also found that sitting time did not predict obesity at follow up, but that body weight predicted sitting time after 5.5 years(26). The second potential explanation is that non-exercise activity thermogenesis may be lower in obese women (29;30). The third explanation is that any relationship between sitting and weight gain is only observable over a longer time period.

In conclusion, the results of this study do not support a role for reducing sitting time as a short term means of weight control in mid-aged women. However, the study of sedentary behavior, defined as time spent sitting, is relatively new and more prospective studies are needed to tease out the potential influence of sitting time on weight gain in women in different BMI categories and age-groups. These studies will need to use valid and reliable measures of sitting time, and sophisticated statistical techniques for longitudinal data analyses. They may also need to examine associations over time periods of decades.

Table 1: Sociodemographic, biological and behavioral characteristics of women in each BMI-group in 2001

	Normal weight (n = 3625)	Overweight (n = 2712)	Obese (n = 1896)	p-value (Chi-square)
Sociodemographic variables	%	%	%	
Marital status				0.0309
married/ partnederd	82	84	81	
single/ separated/ divorced/ widow	18	16	19	
Education[a]				<.0001
low	42	49	53	
intermediate	17	16	17	
trade/ certificate/ diploma	21	21	19	
university degree	19	14	11	
Hours worked				<.0001
not in labour force/unemployed	20	20	26	
1-34 hrs/week	39	36	33	
35+ hrs/week	42	44	41	
Country of birth[a]				0.0001
Australia	76	78	81	
other English speaking	15	14	12	
other non-English speaking	9	8	7	
Area of residence				<.0001
urban	37	33	30	
inner regional	41	40	42	
outer regional/remote	23	26	28	
Biological variables	%	%	%	
Depression				<.0001
no	83	81	74	
yes	17	19	26	
Number of chronic diseases				<.0001

none	51	42	28	
one	30	33	32	
two	12	17	21	
three or more	6	8	19	
Behavioural variables	%	%	%	
Physical activity				<.0001
none	12	16	24	
very low	17	19	18	
low	18	21	17	
moderate	23	25	18	
high	30	20	22	
Energy intake				<.0001
very low	21	20	16	
low	21	19	19	
moderate	20	21	19	
high	20	21	21	
very high	17	19	24	
Smoking status				0.0303
never smoked	55	55	55	
ex smoker	31	33	34	
current smoker	14	12	11	
Alcohol status				
non-drinker	12	15	19	<.0001
low risk drinker	61	56	45	
rarely drinker	19	23	31	
risky drinker	7	7	5	
Continuous variables	Mean (SD)	Mean (SD)	Mean (SD)	p-value (ANOVA)
Sitting time (hrs/day)				
2001	5.21 (2.54)	5.48 (2.49)	6.07 (2.80)	<.0001
2004	5.43 (2.42)	5.75 (2.54)	6.31 (2.69)	<.0001
2007	5.68 (2.48)	5.95 (2.47)	6.57 (2.79)	<.0001
Weight (kg)				

2001	60.50 (6.36)	72.19 (6.82)	90.88 (12.68)	<.0001
2004	61.92 (7.51)	73.24 (8.46)	90.64 (13.80)	<.0001
2007	62.24 (8.07)	73.74 (8.96)	90.80 (14.43)	<.0001
Weight change (%)				
2001-2004	2.42 (6.64)	1.49 (7.06)	-0.08 (8.07)	<.0001
2004-2007	1.26 (6.64)	0.83 (7.22)	0.41 (9.08)	0.0002

[a]variable assessed in 1996; hrs=hours; kg=kilogram; SD=standard deviation; %=column percent.

Table 2: Associations between sitting time and weight in 2001, 2004 and 2007

		Normal weight		Overweight		Obese	
Univariate model		Estimate	95% CI	Estimate	(95% CI)	Estimate	(95% CI)
Slope for sitting (hours/day)		0.04	(0.00, 0.08)	**0.14**	**(0.09, 0.20)**	**0.26**	**(0.17, 0.35)**
Intercept for weight (kilogram)	2001	60.30	(60.01, 60.59)	71.46	(71.06, 71.86)	89.33	(88.52, 90.14)
	2004	61.73	(61.41, 62.06)	72.43	(71.98, 72.89)	89.14	(88.27, 90.00)
	2007	62.40	(62.06, 62.74)	72.86	(72.38, 73.34)	89.08	(88.19, 89.97)
Energy balance model [a]							
Slope for sitting (hours/day)		0.03	(-0.01, 0.07)	**0.13**	**(0.07, 0.18)**	**0.22**	**(0.13, 0.32)**
Intercept for weight (kilogram)	2001	59.61	(59.08, 60.14)	70.55	(69.85, 71.26)	87.51	(85.89, 89.13)
	2004	61.10	(60.54, 61.65)	71.58	(70.84, 72.32)	87.55	(85.90, 89.20)
	2007	61.78	(61.21, 62.34)	72.09	(71.33, 72.84)	87.51	(85.85, 89.17)
Adjusted model [b]							
Slope for sitting (hours/day)		0.05	(0.00, 0.10)	**0.11**	**(0.04, 0.18)**	**0.26**	**(0.14, 0.38)**
Intercept for weight (kilogram)	2001	60.97	(60.06, 61.88)	70.73	(69.49, 71.97)	87.35	(84.62, 90.07)
	2004	62.46	(61.53, 63.38)	71.78	(70.53, 73.04)	87.28	(84.54, 90.01)
	2007	63.31	(62.31, 64.32)	72.96	(71.63, 74.29)	86.71	(83.91, 89.50)

[a]adjusted for exercise status and energy intake; [b]adjusted for exercise status, energy intake, smoking status, alcohol intake, depression, number of chronic diseases, marital status, country of birth, area of residence, education, job status; **Boldface** indicates statistically significant association between sitting time and weight ($p<0.05$).

Table 3: Longitudinal associations between sitting time (2001 and 2004) and percentage weight change (2001-2004 and 2004-2007) by BMI category in 2001

		Normal weight		Overweight		Obese	
Univariate model		Estimate	(95% CI)	Estimate	(95% CI)	Estimate	(95% CI)
Slope for sitting (hours/day)		**0.07**	**(0.01, 0.13)**	**-0.09**	**(-0.16, -0.01)**	-0.01	(-0.10, 0.08)
Percentage weight change	2001-2004	2.05	(1.68, 2.43)	1.93	(1.46, 2.41)	0.01	(-0.65, 0.67)
	2004-2007	0.83	(0.44, 1.21)	1.37	(0.88, 1.87)	0.40	(-0.30, 1.10)
Energy balance model [a]							
Slope for sitting (hours/day)		**0.08**	**(0.02, 0.14)**	**-0.09**	**(-0.16, -0.01)**	0.00	(-0.09, 0.09)
Percentage weight change	2001-2004	1.90	(1.34, 2.47)	1.80	(1.10, 2.50)	-0.21	(-1.24, 0.82)
	2004-2007	0.66	(0.09, 1.23)	1.33	(0.61, 2.04)	0.14	(-0.90, 1.19)
Adjusted model [b]							
Slope for sitting (hours/day)		0.06	(-0.01, 0.12)	-0.08	(-0.16, 0.00)	-0.02	(-0.12, 0.08)
Percentage weight change	2001-2004	0.64	(-0.20, 1.48)	0.66	(-0.42, 1.74)	-0.58	(-2.13, 0.98)
	2004-2007	-0.51	(-1.35, 0.33)	0.14	(-0.94, 1.22)	-0.29	(-1.85, 1.27)

[a]adjusted for exercise status and energy intake; [b]adjusted for exercise status, energy intake, smoking status, alcohol intake, depression, number of chronic diseases, marital status, country of birth, area of residence, education, job status; **Boldface** indicates significant association between sitting time and percentage weight change ($p<0.05$). BMI=body mass index

Table 4: Longitudinal associations between weight (2001 and 2004) and change in sitting time (2001-2004 and 2004-2007) by BMI category in 2001

		Normal weight		Overweight		Obese	
Univariate model		Estimate	(95% CI)	Estimate	(95% CI)	Estimate	(95% CI)
Slope for weight (kilogram)		0.00	(-0.01, 0.00)	0.00	(-0.01, 0.01)	0.00	(0.00, 0.01)
Change in sitting (hours/day)	2001-2004	0.40	(-0.01, 0.81)	0.17	(-0.36, 0.70)	-0.01	(-0.54, 0.52)
	2004-2007	0.39	(-0.04, 0.81)	0.12	(-0.41, 0.66)	0.07	(-0.46, 0.60)

BMI=body mass index

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