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Health Care Costs Associated with Prolonged Sitting and Inactivity

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Background: Physical inactivity and prolonged sitting are associated with negative health outcomes.

Purpose: To examine the health-related costs of prolonged sitting and inactivity in middle-aged women.

Methods: Australian Longitudinal Study on Women's Health participants (born 1946−1951) answered questions about time spent sitting, walking, and in moderate and vigorous leisure activities in 2001 (*n*=6108), 2004 (*n*=5902), 2007 (*n*=5754) and 2010 (*n*=5535) surveys. Sitting time was categorized as low (0−4), moderate (5−7), and high (≥8 hours/day). Physical activity was categorized as inactive (<40), low (40−600), moderate (600−1200) and high (≥1200 metabolic equivalent minutes/week). National health insurance claims data averaged over the survey year ±1 year were used to calculate annual costs (Australian Dollars [AU$]). Differences between categories in median costs were estimated using quantile regression over four surveys with bootstrapped 95% CIs. Analyses were performed in 2013.

Results: In 2010, annual median costs were AU$689 (interquartile range [IQR]=274, 1541) in highly active participants, AU$741 (IQR=279, 1690) in inactive participants, AU$671 (IQR=273, 1551) in participants with low sitting time, and AU$709 (IQR=283−1575) in participants with high sitting time. The difference in median costs for inactive and highly active participants was AU$94 (CI=57, 131) after adjustment for confounders. No statistically significant associations were found between sitting time and costs. When sitting and physical activity were combined, high sitting time did not add to the inactivity-associated increased costs. Associations were consistent across normal weight, overweight, and obese subgroups.

Conclusions: Physical inactivity, but not prolonged sitting, was associated with higher health-related costs in middle-aged women.

Introduction

Physical inactivity is associated with numerous physical and mental health conditions and accounts for approximately 1.5%−3.0% of the total direct health care costs in developed countries.[1] It is estimated that a 10% reduction in the prevalence of inactivity could potentially reduce health care expenditures by 96 million Australian Dollars (AU$) and 150 million Canadian Dollars per year in Australia and Canada (equating to 99 and 129 million U.S. Dollars, respectively).[2, 3] Despite the potential health and economic benefits, only about half the population in developed countries meet the recommended levels of physical activity.[4-6]

In addition to inactivity, prolonged sitting is thought to be associated with negative health outcomes such as weight gain and increased risk of mortality.[7] However, the economic consequences of prolonged sitting remain unknown. Moreover, as some studies have reported interaction effects of physical activity and sedentary time in association with mortality,[8, 9] the combined effects of prolonged sitting and inactivity on direct health care costs may be more important than their individual effects.

A previous study by our group found an interaction with BMI in the relationship between physical activity and health care costs in middle-aged women: costs were lower for overweight active women than for healthy weight inactive women.[10] However, that study did not include measures of sitting time and was cross-sectional in design.

Medicare is the Australian government's system for subsidising the costs of approximately 3800 medical services, including general practitioner and out-of-hospital specialist services, medical diagnostic services such as pathology and radiology, selected dental surgery,

optometry, and allied health services, and limited additional primary health care services, for all Australian citizens and permanent residents.[11] The aim of this study was to examine the total Medicare costs associated with prolonged sitting and physical inactivity in middle-aged women. Associations with costs were examined for sitting and physical activity separately, as well as for combinations of these, referred to as "activity patterns." Potential interaction effects of BMI were taken into account.

Methods

Participants

The Australian Longitudinal Study on Women's Health (ALSWH) is an ongoing study of the health and wellbeing of three generations of women.[12] Samples were randomly drawn from the national Medicare health insurance database, which includes all Australian citizens and permanent residents, with oversampling of women from rural and remote areas. Appropriate ethics approval was obtained from the Ethics Committees of the Universities of Newcastle and Queensland, and informed consent was received from all participants.[12, 13] More details about the study can be found at www.alswh.org.au.

For the current study, data were used from the middle-aged cohort (born 1946−1951). Baseline surveys were mailed in 1996, with the first follow-up in 1998, and then at three yearly intervals to 2010. At baseline, the sample (n=13,715, response rate 54%) was largely representative of Australian women in this age group, but with a somewhat higher representation of partnered women and women with post-high school education.[13] As questions about sitting time were first included in Survey 3 (2001), and costs data were available from 2002 onward, data were used from Surveys 3−6. The respective response rates for these surveys were 81.9%, 79.5%, 77.6%, and 73%. Data were included from participants

who consented to Medicare data linkage (63.9% of those who returned Survey 3) and who were able to walk >100 m unaided (98.1%). Data were excluded from participants with missing values on physical activity (5.0%), sitting (3.7%), or any of the confounders (5.9%). This resulted in data from 6108 women in Survey 3 (2001), 5902 in Survey 4 (2004), 5754 in Survey 5 (2007), and 5535 in Survey 6 (2010).

Health Care Costs

The Australian Medicare system provides a fixed rebate for approximately 3800 medical services,[11] but there is no legislation restricting the amount that doctors may charge. For the current analyses, total annual costs for Medicare-subsidised health services were calculated per participant for the years 2000 to 2010. These costs cover both the government rebate and the "gap" between the government-scheduled fee and the actual fee, which is known as "out-of-pocket expenses" for the participant. To calculate the average costs per survey year, the annual total costs were averaged over the survey year and the years before and after the survey (if available). For example, for Survey 4 (2004), costs were averaged over 2003, 2004, and 2005. However, for Survey 6 (2010), the costs were averaged over 2009 and 2010, as cost data were not available for 2011. Costs are presented in AU$.

Sitting Time

Participants were asked to report the hours per day spent sitting down while doing things like visiting friends, driving, reading, watching television, or working at a desk or computer for a typical weekday and a typical weekend day. A similar question in the International Physical Activity Questionnaire showed good test-retest reliability (intra-class correlation coefficient [ICC]=0.51, 0.93).[14] Data were cleaned as previously described.[15] Hours spent sitting on a weekday and a weekend day were then averaged ([weekday × 5 + weekend day × 2]/7) to estimate the mean sitting time in hours/day, and categorized in approximate tertiles, while

accounting for adverse health outcomes being reported at around 8 hours/day: low=0−4 hours/day, moderate=5−7 hours/day, or high=≥8 hours/day.[8, 9, 16, 17]

Physical Activity

At baseline, leisure-time physical activity was assessed using the modified Active Australia questionnaire, which has acceptable measurement properties (test-retest correlation=0.64, correlation with accelerometry=0.52).[18] Participants reported time in the last week spent walking and in moderate and vigorous leisure-time activities (see www.alswh.org.au for exact wording). Minutes per week spent in each activity were multiplied by a metabolic equivalent (MET) score to reflect the average intensity of the activities in that category: 3.0 for walking, 4.0 for moderate, and 7.5 for vigorous leisure-time activity.[19] As per previously described protocols,[20] total physical activity was calculated as the sum of MET-minutes/week from walking and moderate and vigorous leisure-time activities, categorized as: inactive=0−40, low=40−600, moderate=600−1200, and high=≥1200 MET-minutes/week.

Activity Pattern

Activity patterns were defined on the basis of dichotomous physical activity and sitting time variables: (1) active (≥40 MET-minutes/day)/low sitting time (<8 hours/day); (2) active/high sitting time (≥8 hours/day); (3) inactive (<40 MET-minutes/day)/low sitting time; and (4) inactive/high sitting time.

Sociodemographic and Health Variables

Survey variables were measured using the same methods across surveys (level of education was asked in Survey 1 only), and categorized as shown in Table 1. BMI was calculated using self-reported weight and height values (kg/m^2). Chronic conditions were assessed by asking: "In the past 3 years, have you been diagnosed with or treated for: diabetes/glucose

intolerance, heart disease, stroke, asthma/bronchitis, arthritis, or cancer?" Depressive symptoms were assessed using the ten-item Center for Epidemiologic Studies Depression Scale (CES-D); scores range from 0 to 30 with higher scores indicating more symptoms.[21, 22] Copies of the surveys can be obtained from www.alswh.org.au/surveys.html.

Statistical Analyses

Descriptive statistics were used to summarize sample characteristics for each activity pattern. Continuous, approximately normally distributed variables were presented as means and SDs and group differences were tested using ANOVA. Continuous, non-normally distributed variables were presented as medians and interquartile ranges (IQRs) and group differences were tested using the Kruskal−Wallis test. Categorical variables were presented as percentages and group differences were tested using the chi-squared test.

Medians and IQRs and means and bias-corrected and accelerated 95% bootstrapped CIs for annual costs in 2010 were calculated for each category of sitting and physical activity, separately and for the combined activity patterns. Differences in annual median costs for categories of sitting, physical activity, and activity patterns were examined using quantile regression over four surveys. Quantile regression is the nonparametric equivalent of linear regression; it estimates group differences based on medians rather than means, which was more appropriate given the skewness of the costs data. To account for the within-person correlation of the repeated measures, robust SEs were obtained via bootstrapping. The highest physical activity and lowest sitting time categories were used as the reference categories. Analyses were performed for the whole sample, as well as for strata of BMI, to examine potential effect modification of BMI. All models included the variables' "survey year" to adjust for increasing costs over time due to inflation, and "area of residence" to adjust for

oversampling of rural and remote areas in the original sample. Additional confounders were variables that were significantly associated with the exposure and outcome (but not mediators) and led to a change in the regression coefficient of more than 10%. Potential confounders included marital status, level of education, smoking status, BMI (if no interaction was found), and depressive symptoms. The adjusted analyses were repeated for the 10^{th}, 25^{th}, 75^{th}, and 90^{th} percentile to examine the differences in costs across the range of the costs distribution. All analyses were performed in 2013, using STATA 11.1 (StataCorp L.P., College Station TX). *P*-values were based on two-sided tests and were considered statistically significant at $p<0.05$.

Results

In 2001, the women were an average 52.5 (SD=1.5, range=49−56) years old. The women in the four activity pattern categories differed in demographic and health characteristics (Table 1). In general, inactive women with high sitting time were more often current smokers, had higher BMI, had a higher prevalence of chronic conditions, and scored higher on the depressive symptoms scale than those in the more active categories ($p<0.001$).

Compared with participants who did not consent to data linkage, those who consented were more likely to live in urban areas, had higher levels of education, were less likely to be current smokers, had lower BMI, and fewer depressive symptoms ($p\leq0.01$, data not shown). Women who consented to data linkage were more likely to have high sitting time (i.e., >8 hours/day) and less likely to be inactive ($p<0.001$, data not shown). Compared with participants whose data were excluded owing to missing values, participants with complete data were more often married or in a de facto relationship, had higher levels of education, had

fewer depressive symptoms, were more likely to have a high sitting time, and were less likely to be inactive ($p<0.01$, data not shown).

Annual median and mean costs in 2010 by physical activity, sitting time, and activity pattern categories are shown in Table 2. For physical activity, median costs were highest in the inactive group and lowest in the moderately active group. For sitting, costs were highest in the high sitting time group and lowest in the low sitting time group. When the data for physical activity and sitting time were combined, the expected trends were evident, with lowest costs in the active/low sitting time category. Median costs at each survey are shown for each activity pattern in Figure 1. Median annual costs nearly doubled between 2001 and 2010 in all groups, and were highest in the inactive/high sitting time group from 2001 to 2007. Costs for inactive women did not vary by sitting category.

Differences in median annual costs for women in each of the activity and sitting categories, modeled using data from all surveys, are shown in Table 3. Over this 9-year period, the median cost for inactive participants was AU$162 per year higher than for the most active participants (adjusted for survey year and area of residence). After further adjustment for BMI, depressive symptoms, and smoking status, this difference was reduced to AU$94 per annum. The difference in cost was greater at higher percentiles of the costs distribution. Cost differences for women in the three sitting time categories were small and not significantly different from each other across the range of the cost distribution. For activity patterns, median annual costs were AU$130 and AU$189 higher in the inactive/low sitting time and inactive/high sitting time categories, respectively, than in the inactive/low sitting time category. These values were attenuated to AU$84 and AU$110 in the adjusted models. The difference in cost was greater at higher percentiles of the costs distribution, but with wide CIs.

When analyses were fitted for BMI strata, costs were consistently higher for obese women (median annual costs [IQR]: normal weight, AU$561 [266, 1091]; overweight, AU$615 [299, 1236]; obese, AU$718 [340, 1430]), but the patterns of association were similar to those observed in the overall analysis (Table 4). For physical activity, annual costs were higher in the inactive category than in the high category, in the normal weight, overweight, and obese subgroups. Similarly, for activity patterns, annual costs were higher in the inactive/high sitting time category than the active/low sitting time category in the normal weight, overweight, and obese subgroups.

Discussion

This is the first study to examine health costs associated with both inactivity and prolonged sitting in a longitudinal context. The results showed that in middle-aged women, physical inactivity, but not prolonged sitting, was associated with higher health-related costs. When the combination of physical activity and sitting time were examined, physical inactivity was associated with increased costs, regardless of sitting time. These findings were consistent across normal weight, overweight, and obese subgroups.

In line with other cross-sectional and prospective studies,[10, 23-27] the current longitudinal model suggested higher costs in inactive than highly active adults. As previous studies differed in sample characteristics, timing, study design, and statistical analyses, this association appears to be robust and consistent across subgroups of adults and over time. The magnitude of the (adjusted) difference in median annual health-related costs between the inactive and highly active categories was AU$94. It is estimated that about 15% of the almost 3 million Australian women in the 45−65 years age group are inactive. If these women increased their activity levels, a reduction of AU$94 per woman would translate to a savings

of nearly AU$40 million per annum in healthcare costs. The cost savings could be even higher if some of the women with the highest costs (90th percentile) could improve their activity levels.

Given the evidence for increased risks of diabetes and cardiovascular disease in adults with high levels of sedentary behavior,[28] it was expected that there might be higher health-related costs in women with high sitting time. However, in this large sample of middle-aged women, there were no differences in costs between high and low levels of daily sitting time across the range of the cost distribution. Furthermore, in line with the separate results for sitting and physical activity, the results for the two factors combined showed that inactivity, rather than prolonged sitting, was associated with higher costs. Thus, prolonged sitting did not significantly add to the higher costs associated with inactivity. One explanation for this lack of an association may be that, in the context of other risk factors for these conditions, the risk attributable to sedentary behaviour is relatively small. This is supported by studies that examined associations between sitting and all-cause mortality in middle-aged women, which found statistically significant but small adjusted hazard ratios [HRs] (HR=1.10[29] and HR=1.34[30] for the highest level of sitting).

Several previous studies have assumed interactions between physical activity and BMI and presented results stratified by BMI.[10, 23, 31, 32] Although costs are higher in obese and overweight individuals than in normal weight individuals,[10, 23] in line with other studies, the current results show that the effects of physical activity on costs were similar across normal weight, overweight, and obese subgroups.[10, 23, 32] These findings suggest no BMI interaction effect. Furthermore, three of the previous studies concluded that associations with costs were stronger for inactivity than for overweight/obesity.[10, 23, 31]

Strengths of this study include the large population-based sample of middle-aged women and use of national registry data to calculate the health-related costs. The original ALSWH sample was representative of the middle-aged female population in Australia[13]; however, for the current analyses, a subsample of women who consented to data linkage was used. The women in this subsample were less likely to be smokers, had lower BMI, and fewer depressive symptoms than those who did not consent to data linkage. Hence, the estimated median costs are likely to underestimate the actual costs at the population level.

Although use of national administrative data for costs ensures completeness of the data for the 3800 Medicare-subsidized items, a limitation is that not all health services are subsidized (particularly public hospitals, which are funded separately), and their costs are not registered in this database.[11] Subsidy is available for prescription medication in specific circumstances, but these costs are registered in a separate database and were thus not included in the current analyses. The results therefore do not represent the total healthcare costs, but only the costs for services with a Medicare subsidy.

Another limitation is that both the sitting and physical activity measures were self-reported, which could have resulted in some measurement error and attenuation of the estimated group differences. This may be particularly true for the generic sitting time measure. However, previous ALSWH analyses have shown associations between this sitting measure with body weight, breathing difficulty and chest pain, and mortality,[15, 17, 33] and other studies have demonstrated relationships with mortality using similar generic measures.[16] Notwithstanding, misclassification may have resulted in underestimation of the true effect of sitting time on health-related costs. To our knowledge, no other studies have examined the costs associated

with (measures of) sedentary behavior. Further research, preferably with objective measurement of sitting time, is warranted.

In conclusion, the current results suggest that physical inactivity, but not prolonged sitting, were associated with higher health-related costs in middle-aged women. After controlling for other health indicators, the median health-related costs were AU$94 per annum higher in physically inactive participants than in those who engaged in any physical activity, which could translate to AU$40 million per year at the population level. These findings were consistent across normal weight, overweight, and obese subgroups.

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Figure Title

Figure 1. Annual median costs (Australian Dollars [AU$]) in each of the activity patterns from 2001 to 2010

Table 1. Sample characteristics at study baseline (2001) for each of the activity patterns[a]

Physical activity	Inactive	Inactive	Active	Active	*p*
Sitting time	High	Low	High	Low	
n (%)	289 (4.7)	676 (11.1)	1208 (19.8)	3935 (64.4)	
Age (M [SD])	52.5 (1.4)	52.4 (1.5)	52.5 (1.4)	52.5 (1.5)	0.93
Area (%)					**<0.001**
Urban	46.0	32.8	47.5	35.6	
Rural	50.2	61.5	49.2	60.2	
Remote	3.8	5.6	3.3	4.2	
Marital status (%)					**<0.001**
Married/de facto	73.2	82.9	76.5	84.4	
Separated/divorced/widowed	19.9	15.0	19.0	13.5	
Single	7.0	2.1	4.6	2.1	
Education (%)					**<0.001**
No formal qualification	18.1	20.5	10.2	11.7	
School certificate	36.8	36.1	29.1	31.2	
Higher school certificate	16.7	16.3	18.9	16.7	
Trade/apprentice	14.6	17.6	20.2	23.1	
University degree or higher	13.0	9.6	21.6	17.3	
Smoking status (%)					**<0.001**
Never smoked	49.8	58.7	60.1	63.3	
Ex-smoker	27.7	24.9	26.9	25.6	
Current smoker	22.5	16.4	13.0	11.1	
BMI (M [SD])	29.8 (7.2)	28.1 (6.3)	27.2 (5.6)	26.2 (4.9)	**<0.001**
Chronic conditions (% ≥1)	46.7	40.8	34.3	34.7	**<0.001**

Depressive symptoms (median [IQR])	6 [3, 10]	6 [3, 10]	4 [2, 9]	4 [2, 8]	**<0.001**

Note: Boldface indicates statistically significant values ($p<0.05$).

Group differences in means were tested using ANOVA, group differences in medians were tested using the Kruskal−Wallis test, and group differences in proportions were tested using the chi-square test.

[a]Participants were categorized according to activity pattern based on level of physical activity (inactive: <40 MET-minutes/week; active: ≥40 MET-minutes/week) and sitting time (low: <8 hours/day; high: ≥8 hours/day).

IQR, interquartile range; MET, metabolic equivalent

Table 2. Median and mean health care costs, 2010

Physical activity (MET-minutes/week)	Sitting time (hours/day)	*n*	Health care costs in 2010 (AU$)			
			Median	IQR	M	CI
High (≥1200)		1554	689	274, 1541	1258	1180, 1386
Moderate (600−1200)		1271	623	252, 1457	1282	1210, 1457
Low (40−600)		2318	693	288, 1568	1347	1288, 1488
Inactive (<40)		965	741	279, 1690	1438	1312, 1611
	Low (≤4)	227	671	273, 1551	1263	1191, 1336
	Moderate (5−7)	2806	684	270, 1532	1343	1242, 1450
	High (≥8)	1025	709	283, 1575	1393	1297, 1551
Active (≥40)	Low (<8)	3935	668	270, 1529	1282	1223, 1336
Active (≥40)	High (≥8)	1208	705	282, 1534	1375	1310, 1479
Inactive (<40)	Low (<8)	676	741	279, 1651	1425	1295, 1589
Inactive (<40)	High (≥8)	289	760	288, 1783	1470	1304, 1698

AU$, Australian Dollars; IQR, interquartile range; CI, bias-corrected and accelerated bootstrapped 95% CI; MET, metabolic equivalent

Table 3. Differences in health care costs (AU$) averaged over 2000 to 2010

Physical activity (MET-minutes/week)	Sitting time (hours/day)	Model 1	Model 2				
		Median d (CI)	p10 d (CI)	p25 d (CI)	Median d (CI)	p75 d (CI)	p90 d (CI)
High (≥1200)		0	0	0	0	0	0
Moderate (600−1200)		31 (1, 16)	−5 (−20, 9)	7 (−4, 19)	15 (−15, 46)	10 (−32, 51)	6 (−110, 121)
Low (40−600)		18 (−12, 47)	−7 (17, 3)	3 (−10, 16)	−9 (−36, 18)	5 (−38, 48)	−16 (−99, 66)
Inactive (<40)		162 (134, 190)	5 (−5, 16)	38 (11, 65)	94 (57, 131)	197 (122, 273)	380 (264, 495)
	Low (≤4)	0	0	0	0	0	0
	Moderate (5−7)	6 (−14, 26)	1 (−9, 11)	−2 (−11, 7)	−9 (−30, 12)	5 (−47, 56)	15 (−90, 120)
	High (≥8)	11 (−14, 36)	−6 (−24, 11)	−11 (−22, 0)	−16 (−39, 7)	−26 (−7, 18)	−6 (−125, 114)
Active (≥40)	Low (<8)	0	0	0	0	0	0
Active (≥40)	High (≥8)	−12 (−33, 9)	−4 (−12, 3)	−8 (−20, 4)	−22 (−47, 4)	−29 (−86, 29)	4 (−101, 110)
Inactive (<40)	Low (<8)	130 (99, 161)	5 (−11, 21)	28 (11, 46)	84 (54, 113)	175 (71, 279)	329 (161, 497)
Inactive (<40)	High (≥8)	189 (145, 234)	27 (−7, 61)	49 (13, 85)	110 (39, 182)	202 (94, 310)	423 (−25,

871)

Model 1: adjusted for survey and area of residence.

Model 2: additionally adjusted for BMI, depressive symptoms, and smoking status.

AU$, Australian Dollars; d, difference in median, 10^{th}, 20^{th}, 75^{th} and 90^{th} percentile health care costs relative to the reference category; CI, 95% CI based on variance-covariance matrix of the estimators obtained by bootstrapping; MET, metabolic equivalent

Table 4. Differences in median health care costs (AU$) stratified for BMI averaged over 2000 to 2010

Physical activity (MET-minutes/week)	Sitting time (hours/day)	BMI<25		BMI=25−30		BMI>30	
		d	CI	d	CI	d	CI
High (≥1200)		0		0		0	
Moderate (600−1200)		11	−27, 49	7	−39, 53	31	−18, 79
Low (40−600)		−2	−34, 30	−32	−69, 6	3	−61, 67
Inactive (<40)		66	3, 129	111	56, 167	104	25, 182
	Low (≤4)	0		0		0	
	Moderate (5−7)	−7	−39, 26	−35	−75, 5	28	−46, 102
	High (≥8)	3	−38, 43	−56	−96, −16	−10	−63, 43
Active (≥40)	Low (<8)	0		0		0	
Active (≥40)	High (≥8)	−18	−48, 13	−34	−88, −19	−23	−76, 30
Inactive (<40)	Low (<8)	48	−17, 113	94	29, 160	99	72, 127
Inactive (<40)	High (≥8)	129	53, 204	128	59, 197	81	−19, 181

All results were presented after adjustment for survey area of residence, depressive symptoms, and smoking status.

AU$, Australian Dollars; d, difference in median health care costs relative to the reference category; CI, 95% CI based on variance-covariance matrix of the estimators obtained by bootstrapping; MET, metabolic equivalent

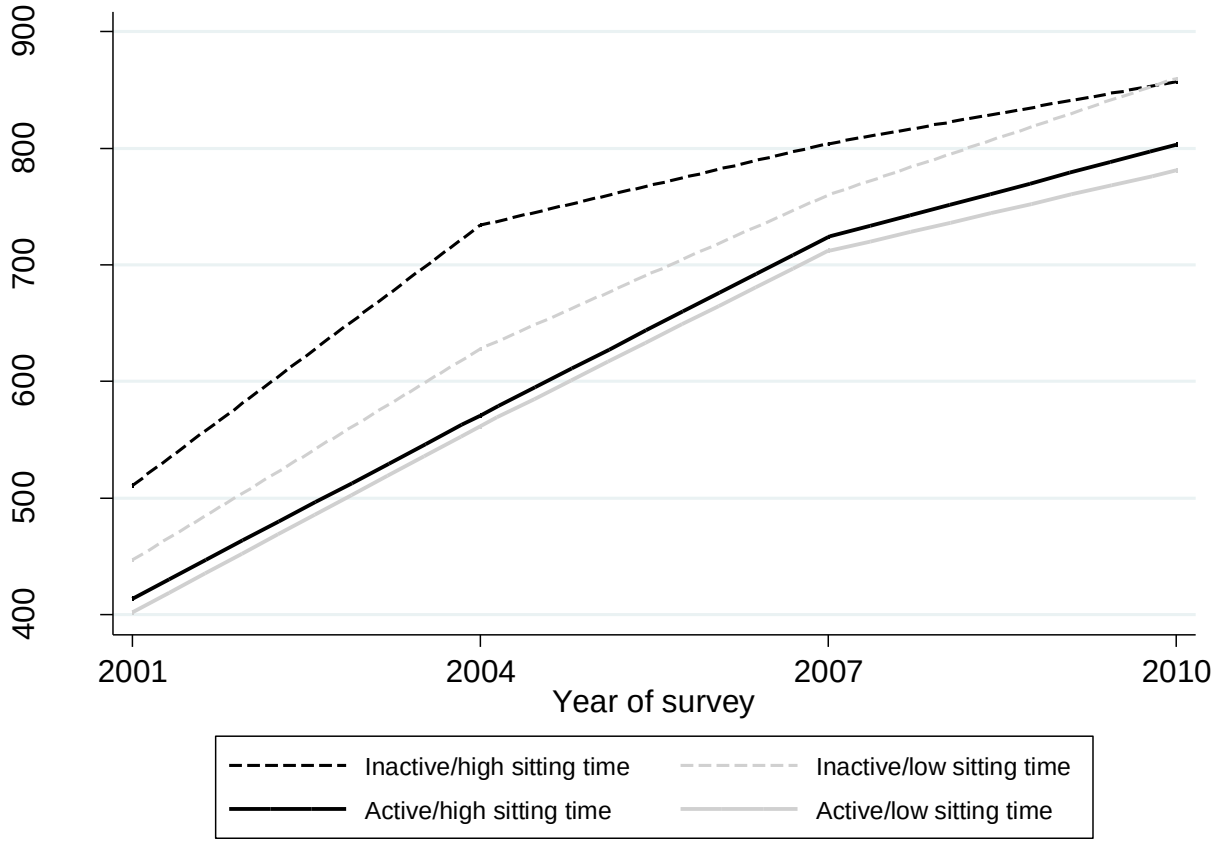

Figure 1. Annual median costs (Australian Dollars [AU$]) in each of the activity patterns from 2001 to 2010. Participants were categorized according to activity pattern based on physical activity level (inactive: <40 metabolic equivalent [MET]-minutes/week; active: ≥40 MET-minutes/week) and sitting time (low: <8 hours/day; high: ≥8 hours/day).