Associations of sitting time with leisure-time physical inactivity, education and BMI change

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Abstract

We aimed to investigate the associations of long-term leisure-time physical inactivity, body mass index (BMI) change, and education with sitting time in a 35-year follow-up based on self-reports in surveys. Influences of working status in 2011 and familial confounding on the associations were tested. Data were based on the population-based Finnish Twin Cohort of 5232 twins (53–67-year-old, 41% men) with four surveys in 1975-2011. Statistical analyses were performed using linear regression with several covariates. The effect of familial confounding (genetics and shared environment) was analyzed using a co-twin control design which should be interpreted as if familial confounding plays a role, an association should be seen among all individuals but not in discordant twin pairs. Compared to those not at work, those at work had a longer total sitting time/day. For those at work, higher education was associated with more total sitting but with less non-work sitting. Long-term leisure-time physical inactivity was associated with more non-work sitting among those at work, whereas long-term weight gain with more total and non-work sitting regardless of working status. Familial confounding attenuated the associations, except for the association of increasing BMI with total and non-work sitting among women at work. To conclude, total sitting time was longer among those still at work, but it was also influenced by long-term leisure-time physical inactivity, higher education, and an increase of BMI over the years. Public health efforts should be targeted to reduce sedentary behavior by promoting life-long leisure-time physical activity and weight control.

Key words: Adults, Exercise, Follow-up cohort study, Sedentary behavior, Sitting, Twins, Work

INTRODUCTION

Sitting for long periods of time poses a risk for weight gain, cardiovascular diseases, type 2 diabetes, cancers, and premature death [1, 2]. Instead, strong evidence exists that leisure-time physical activity (LTPA) is beneficial for health [3]. In previous studies, the associations between the length of overall daily sedentary time, in terms of sitting time, and an increased incidence of many chronic diseases or mortality have been shown to be independent from LTPA, suggesting that engagement in LTPA does not necessary protect from the negative health effects of long sitting [4]. In recent meta-analyses, this evidence has been challenged [1, 2]. As expected, high amount of LTPA has been associated with less sitting time [5, 6]. Previous studies have also shown that those with a high amount of work-related sitting do less LTPA [7, 8]. Thus, no systematic consensus exists about protective effect of LTPA in sedentary behavior and its negative health consequences. Also whether lower LTPA is associated with a greater sitting duration or vice versa merits further studies. Furthermore, associations of LTPA and other health behaviors such as weight gain with sitting can be mutual and complex because health behaviors tend to vary over time [9, 10].

Longitudinal studies are warranted to clarify not only the mutual associations between the health behaviors and sitting, but also their link with other influential factors such as education. Education level is known to be associated both with LTPA and sitting time [11, 12], but in a complex way. Evidence exists that those with higher education do more LTPA compared to those with lower education [13]. On the other hand, more educated adults report more daily sitting [5] and long sitting durations are especially common in desk-based work [14, 15]. However, sitting varies across numerous contexts, including work, home, recreation, and commuting [16], and actually a majority of sitting is reported to take place elsewhere than at work [7, 8]. Hence, the role of education on sitting time may differ over domains of sitting.

Another factor affecting sitting time is relative body weight, typically assessed as body mass index (BMI). Cross-sectional evidence shows higher BMI being associated with longer sitting time at work [14] although not in all studies [8]. Some longitudinal studies have indicated obesity being associated with increased sitting among working age population [17] and higher BMI with more sitting among young women [12]. Furthermore, high BMI [9, 18] and weight gain [9] have been shown to be linked with a lower level of LTPA. On the contrary, long-term regular LTPA prevents excess weight gain [10, 19]. Overall, the associations between sitting time, LTPA, education, and BMI are complex due to their mutually associations. For example, those with high education report to sit more [5], but also being more active in LTPA [20], have lower BMI [21], and gain less weight during their adulthood [22] compared to those with less education. Education also has a strong association with other health behaviors [23], and thus it may have an important role as a moderator between sedentary behavior and health. However, further knowledge is needed to determine the associations of education, long-term weight gain or long-term LTPA with sitting and to assess whether being at work or not would modify these associations.

A further important aspect is that education, BMI, sitting time, and LTPA have moderate to strong genetic components [24-27] and may also share genetics and familial background in common. Therefore, familial confounding (i.e. genetics and shared environment, mainly in the childhood) might influence their associations. Twin studies provide a unique opportunity to analyze the effect of familial confounding [28]. Dizygotic (DZ) twin pairs share, on average, 50% of their segregating genes (as full siblings), whereas monozygotic (MZ) twin pairs are virtually identical on the gene sequence level. Both type of twins shares the same social background including home and family environment. The interpretation of twin analyses implies that if the associations for the whole cohort, when twins are analyzed as individuals, clearly attenuate when analyzing the associations among twin pairs then familial confounding plays a role. Instead, if the associations are at about the same level for the whole cohort and within DZ twin pairs, but the association diminish within MZ twin pairs, then genetics play a role. Thirdly, if the associations remain equally strong both for the whole cohort and for within twin pairs, then the associations are independent from familial confounding i.e. providing evidence for a direct association.

The aim of the study was to investigate how long-term LTPA, BMI change, and education were associated with total and non-work sitting time among a Finnish adult twin cohort followed for 35 years by self-reports in surveys. Our additional aim was to consider the possible modifying effect of working status and familial confounding on the associations.

METHODS

The study was based on the population-based Finnish Older Twin Cohort, with four questionnaire-based postal surveys implemented in 1975, 1981, 1990, and 2011 [29]. In these surveys, the participation rates varied from 72% to 89% [10]. The study protocol was designed and performed according to the principles of the Declaration of Helsinki and was approved by the Ethical Committee of the University of Helsinki, Department of Public Health. We included individuals born between 1945 and 1957 who were invited to participate in the last survey in 2011. In order to follow BMI change and LTPA behavior over the 35-year period (1975 – 2011), the analyses were restricted to those 5575 participants who had participated in all four surveys. Among them, 321 (6% of the total sample) had missing or incomplete LTPA data in at least one survey and were therefore excluded from the analyses. The selection bias in the cohort and the sampling bias in restricting the analyses to those participants with complete LTPA data have been reported in detail earlier [10, 30], indicating no differences in mortality between 1975 and 2011 or in participation in the last survey between those active and inactive in their leisure-time physical activity at baseline in 1975. Eight participants had not reported any information about their sitting time, and 14 individuals had missing information about their working status in 2011 and were therefore excluded from the analyses. The final sample consisted of 5232 participants, including 1587 twin pairs with both co-twins in the sample (Table 1).

Table 1. Percentages, frequencies and means with standard deviations (SD) of characteristics in 1981 and leisure-time physical (in)activity (LTPA) for men and women by working status in 2011 among 5232 twin individuals.

	Men (n=2134)				Women (n=3098)			
	At work in 2011 (n = 1082)		Not at work in 2011 (n = 1052)		At work in 2011 (n = 1643)		Not at work in 2011 (n = 1455)	
Characteristics in 1981	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Social class (1975)								
Upper white collar	50	5	112	11	39	2	62	4
Lower white collar	146	14	211	20	525	32	572	39
Skilled worker	499	46	527	50	466	28	473	33
Unskilled worker	87	8	81	8	156	10	172	12
Farmer	57	5	54	5	20	1	52	4
Other (including students)	239	22	63	6	433	26	124	9
Marital status								
Married or living together	661	61	781	74	1124	68	1086	75
Smoking status								
Never-smoker	462	43	356	34	868	54	790	55
Former smoker	240	22	266	26	367	23	261	18
Occasional smoker	2	0	9	1	23	1	21	1
Current daily smoker	378	35	421	40	385	24	383	27
LTPA								
Active (>1.5 MET-h / day)	597	55	554	53	881	54	720	49
Inactive (≤1.5 MET-h / day)	485	45	498	47	762	46	735	51
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age (years)	28.4	2.9	32.4	3.4	28.0	2.8	32.1	3.5
Education (years)	9.4	3.2	8.3	2.9	9.6	3.1	8.4	2.7
BMI (kg/m^2)	23.0	2.5	24.1	2.8	21.2	2.5	22.3	3.2
Alcohol consumption (g/day)	9.7	11.4	12.5	13.3	4.1	5.6	4.3	6.8
Follow-up in 2011								
Total sitting time (min/day)	464	171	311	120	430	151	310	115
Non-work sitting time (min/day)	294	114			257	92		

LTPA= leisure-time physical activity, MET= metabolic equivalent of task

The duration of *daily sitting time* was queried at one time point, 2011 [27]. The participants reported how many hours (h), on average, they sit per day in different activities: 1) at the office or similar places (at work), 2) at home watching television or videos, 3) at home at the computer, 4) in a vehicle, and 5) elsewhere utilizing four alternatives: a) < 1 hour, b) 1 to <2 hours, c) 2 to <4 hours, d) ≥4 hours. Daily *total sitting time* was the sum of the midpoints of all sitting activities including sitting at work, using 30 minutes for <1 h, 90 minutes for 1 to <2 h, 180 minutes for 2 to <4 h, and 300 minutes for ≥4 h. For analyses, we divided total sitting time into work time and non-work time (i.e. the sum of all other reported sitting-time domains) for people at work. For participants not at work, total sitting time was thus the same as non-work sitting time. Missing information in one or more, but not in all five sitting time domains, was allowed in calculating the sum of total and non-work sitting times by replacing the missing information on sitting activity with zero.

Leisure-time physical activity (LTPA) was queried in all four surveys and consisted of responses on the frequency (per day, week or month), and duration (per session). The intensity of LTPA was queried with "Is your leisure-time physical exercise on average as intensive as…," using four response alternatives: walking (4 metabolic equivalent of task [MET]), walking and jogging (6 MET), jogging (10 MET), or running (13 MET). Daily time for commuting by physically active means (4 MET) to and from work was also queried. Then, the daily MET index for exercising and commuting was calculated by multiplying the general intensity of activity and the average duration (per session) and frequency (per month) of activities at each time point. For the total LTPA MET index, exercise and commuting MET indexes were summed together and converted into MET hours/day (MET-h/day). In each survey, everyone was categorized into inactive (≤1.5 MET-h/day) and active (>1.5 MET-h/day). Further, everyone was assigned to one of seven long-term LTPA categories that constructed a pattern of LTPA during the 35-year follow-up presented earlier [10]. The LTPA questions, MET calculations, categorization of inactive individuals, and the 35-year LTPA behavior for this cohort have earlier been reported in detail [10, 27]. The intraclass correlations between this survey-based MET index and the interview-based MET index has been 0.56 in a subsample of the Finnish Twin Cohort [31]. This is in line with previous findings between self-reported and direct measures of physical activity [32, 33].

For the statistical analyses, we categorized the LTPA into four classes: broadly inactive (i.e. persistently inactive, mainly inactive, and a change from active to inactive), mixed behavior, active (mainly active, a change from inactive to active), and persistently active to retain power in the statistical analyses. However, for the discordant pair analyses, LTPA was dichotomized into broadly inactive (i.e. persistently inactive, mainly inactive, and a change from active to inactive) and broadly active (mainly active, a change from inactive to active, and persistently active), excluding participants with mixed LTPA behavior.

Working status was categorized as at work or not at work based on the single question in 2011 to report their working status. Highest attained education was available in 1981 as *years of education* (range 3–16 years) [30]. For sensitivity analyses, we also categorized education by the median years of education in the sample (≤7 years vs. ≥8 years). *Body mass index (BMI)* was computed from self-reported weight and height (kg/m^2), which were elicited at each survey with a high validity of self-reported BMI in 1990 [34] and in 2011 (unpublished data, under review). The mean BMI change was calculated by subtracting BMI in 1975 from BMI in 2011. For sensitivity analyses, we also calculated BMI change from 1975 to 1990.

Covariates were assessed in 1981, except for s*ocioeconomic status*, which was elicited from occupation reported in 1975 and consisted of six categories based on the Statistics Finland 1970 census classification: upper and lower non-manual workers, skilled and unskilled manual workers, farmers, and others (including students, conscripts, full-time homemakers, and otherwise not classified). Other covariates were *age* (years), *marital status* (dichotomized as single/divorced/widowed vs. married/cohabiting), *alcohol consumption* (grams of absolute alcohol per day, based on the average consumption of beer, wines, and spirits in the past month), and *smoking status* (never smoker, former smoker, occasional smoker, current daily smoker).

Statistical methods

The interactions between sex or working status and education, 35-year BMI change, and 35-year LTPA behavior on total sitting time were tested with a log-likelihood test. Statistically significant interaction was found between sitting time and sex ($p<0.001$) and between BMI change 1975–2011 and sex ($p=0.024$), but not for other associations. Therefore, men and women were analyzed together using sex as a covariate in all other analyses except in analyzing the associations for BMI change. In addition, significant interactions on total sitting time were found between working status and education ($p<0.001$) and between working status and 35-year BMI change ($p=0.007$). Based on the significance of interaction, all the analyses were stratified by working status in 2011 (at work vs. not at work).

Linear regression models were calculated for regression coefficients with 95% Confidence Intervals (CI) for the whole cohort (twins treated as individuals). Analyses were performed separately for the total sitting time and the non-work sitting time. First, the regression models were adjusted for age and sex. Baseline (1975) BMI was controlled in the analyses of the associations of BMI change. Second, we added marital and socioeconomic status, smoking, alcohol consumption, and BMI to the models.

For the final step, we analyzed confounding by familial factors on the associations between sitting time and 35-year LTPA, 35-year BMI change and education applying the co-twin control design, among two strata of the data (Digital supplement). Pairs concordant for their working status, i.e. both were working or neither worked, were identified and within-pair analyses between sitting time and the putative exposure were conducted. First, we utilized the within pair correlations (Pearson correlation coefficient) for within pair difference in sitting times and for the two continuous measures, i.e. education and 35-year BMI change. For the 35-year LTPA behavior, we used the dichotomous definition of broadly active vs. broadly inactive categorization to see the differences in LTPA using the point biserial (i.e. for a dichotomous variable vs. continuous one) correlation coefficients.

Stata SE version 14.1 (StataCorp, College Station, Texas, USA) was used for all analyses. Due to the within pair dependence of twin individuals, a cluster option was used to control the effect on standard errors [35].

RESULTS

In 2011, the mean age of the 5252 participants (41% men) was 60 years (range 53–67), and BMI was 26.2 (SD 4.3). The proportion of inactive participants was 36%, and 48% were not at work in 2011. The sex-specific characteristics in 1981 by working status in 2011 are presented in Table 1. The mean sitting times in 2011 were 380 minutes (SD 156 minutes, range 30–1110 min) for total sitting in all participants and 272 minutes (SD 103, range 0–870 min) for non-work sitting among those at work. Men were sitting 15 min more than women (mean 389 [SD 167] in men; mean 374 [SD 148] in women) in total and 37 minutes more in their free time if they were still at work (Table 1). The mean work-related sitting time was 173 minutes (SD 116 min) and was similar in both sexes (mean 171 [SD 114] in men; mean 174 [SD 118] in women). Those who were at work had a longer total sitting time than those not at work (difference in means 133 min).

Sitting time across LTPA categories

Overall, the proportion of broadly inactive individuals during the 35-year follow-up was 25%, whereas 18% were persistently active. The proportions of long-term LTPA by work status are shown in Table 2. Compared with persistently active participants, inactive participants were sitting approximately 16–30 minutes longer per day in 2011. Among those at work in 2011, statistically significant association between physical inactivity and longer sitting time was seen only in non-work sitting and the association remained in the fully adjusted models.

Table 2. Linear Regression model coefficients with 95% confidence intervals [CI] for the association of 35-year leisure-time physical activity (LTPA) (1975–2011) or education in 1981 with total and non-work sitting time (in minutes) in 2011 among 5232 twin individuals by their working status in 2011.

		Total sitting time (minutes)				**Non-work sitting time (minutes)**			
		Model A		**Model B**		**Model A**		**Model B**	
35-year LTPA		(n=2725)		(n=2635)		(n=2725)		(n=2635)	
At work in 2011	**%**	**B**	**95% CI**	**B**	**95% CI**	**B**	**95% CI**	**B**	**95% CI**
Broadly inactive	20	9.1	-10.5, 28.8	16.2	-3.2, 35.6	**27.5**	**15.5, 39.5**	**20.4**	**8.4, 32.3**
Mixed	18	15.8	-4.3, 35.9	**20.4**	**0.9, 39.9**	**21.3**	**9.0, 33.6**	**18.0**	**5.7, 30.3**
Mainly active	42	6.4	-9.6, 22.3	11.3	-4.3, 27.0	**11.6**	**2.3, 20.8**	**11.4**	**2.0, 20.8**
Persistently active	20	reference	-	reference	-	reference		reference	-
	mean								
Education in years in 1981	9.5	**9.9**	**8.1, 11.7**	**7.5**	**5.1, 9.9**	**-3.7**	**-4.9, -2.6**	**-2.9**	**-4.4, -1.4**
Not at work in 2011	**%**	n=2507		n=2400					
Broadly inactive	31	**31.8**	**17.9, 45.7**	**28.7**	**14.3, 43.2**				

Mixed	19	**24.7**	**9.7, 39.6**	**20.6**	**5.5, 35.8**
Mainly active	34	**14.6**	**1.9, 27.4**	10.9	-2.2, 24.1
Persistently active	16	reference	-	reference	-
	mean	n=2507		n=2400	
Education in years in 1981	8.4	-1.0	-2.6, 0.6	0.4	-1.8, 2.6

Regression coefficients (B) with statistical significance (p-value <0.05) **bolded**.
Model A: Age- and sex-adjusted model.
Model B: Age, sex education in 1981, marital status in 1981, socioeconomic status in 1975, smoking status in 1981, alcohol consumption in 1981, and body mass index in 1981 are included as covariates in the model.

Education and sitting time

Among those at work in 2011, each additional year of higher education increased the total sitting time about 10 minutes (age- and sex-adjusted regression coefficient 9.9 [95% CI 8.1, 11.7]) (Table 2). The association attenuated but remained statistically significant in the fully adjusted model. Regarding non-work sitting time, each year of education was associated with 3 minutes less sitting among those at work both in age- and sex- and fully adjusted models. In the sensitivity analyses, those with higher than median years of education (>7) and at work in 2011 had 66 minutes longer sitting time (95% CI 54 to 79 min) but had 18 minutes shorter (95% CI 10 to 25 min) non-work sitting time compared to those with a lower education level. Education was not associated with total sitting time among those not at work in 2011.

BMI change and sitting time

During the 35-year follow-up, the mean BMI change was 4.6 kg/m^2 (SD 3.7, range -11.6 - 30.7), being highest among men at work in 2011 (with an average weight gain of 13.8 kg)

(Table 3). Each one-unit increase in BMI was associated with an increase of 7 minutes in total sitting time for those at work and 3 minutes among those not at work. Among men at work, each one-unit increase in BMI was associated with 12 minutes longer total sitting time. The associations remained in the fully adjusted models and were at the same magnitude for non-work sitting time, except for total sitting time in men not at work. In the sensitivity analyses, each one-unit increase in BMI change (1975–1990) was associated with a longer total sitting time regardless of working status (age-, sex-, and BMI-adjusted regression coefficient 5.8 [95% CI 3.1 to 8.5] for those at work and 3.1 [95% CI 1.0 to5.2] for those not at work).

Table 3. The mean change in weight and in body mass index (BMI) between 1975 and 2011, and linear regression model coefficients with 95% confidence intervals [CI] for the associations of each BMI unit change during a 36-year follow-up (1975–2011) with total and non-work sitting time (minutes) in 2011 among the 5118* twin individuals by their sex and working status in 2011.

BMI by working status in 2011	**Mean 36-year Δ weight change in kg**		**Mean 36-year Δ BMI change**		**Total sitting time (minutes)**				**N**
					Model A (n =2678)		**Model B** (n =2606)		**Mode**
At work in 2011	**mean**	**95% CI**	**mean**	**95% CI**	**B**	**95% CI**	**B**	**95% CI**	**B**
Men (n=1066)	13.8	13.2, 14.4	4.4	4.2, 5.6	**11.9**	**8.5, 15.3**	**11.3**	**7.9, 14.7**	**6.7**
Women (n=1612)	12.8	12.3, 13.3	4.9	4.7, 5.0	**4.50**	**2.2, 6.8**	**4.5**	**2.3, 6.7**	**3.9**
Not at work in 2011					n=2440		n=2349		
Men (n=1022)	11.5	10.8, 12.2	3.8	3.6, 4.0	**2.3**	**0.1, 4.6**	2.3	-0.02, 4.6	
Women (n=1418)	13.2	12.6, 13.7	5.1	4.9, 5.3	**4.0**	**2.5, 5.6**	**4.1**	**2.5, 5.7**	

BMI= body mass index (kg/m^2). Regression coefficients (B) with statistical significance (p-value <0.05) **bolded**.
*Those who reported information about their weight and height both in 1975 and in 2011.
Model A: Age, sex, and BMI 1975 adjusted model for all participants, and age and BMI 1975 adjusted for sex stratified models.
Model B: Age, sex, BMI 1975, education in 1981, marital status in 1981 and socioeconomic status in 1975, smoking status in 1981, alcohol consumption in 1981, and leisure-time

physical activity in 1981 are included as covariates in the model. Sex was excluded from the full adjusted and sex-stratified models.

Familial confounding in the associations

Overall, the correlation coefficients between total or non-work sitting, and LTPA, education and BMI change were weak both for participants and for within pairs differences but pointed towards familial confounding in the associations between long-term LTPA behavior or education and sitting variables regardless of working status (Table 4). However, among women at work, the DZ and MZ correlations were not attenuated compared to the participants, which supports the assumption that an increase in BMI would increase both total and non-work sitting time.

Table 4. Correlation coefficients for total sitting time or non-work sitting time and 35-year leisure-time physical activity (LTPA) behavior, education in 1981, and 35-year BMI change for twin individuals (n=4272)* and within pair differences for full twin pairs (n=1056 pairs)* stratified by working status and sex

	Total sitting time				**Non-work sitting time**			
		Within pair analyses **				**Within pair analyses ****		
Working status in 2011	**All individuals**	**All pairs**	**DZ pairs**	**MZ pairs**	**All individuals**	**All pairs**	**DZ pairs**	**MZ pairs**
				35-year LTPA behavior[1]				
At work	n=2236	n=410	n=234	n=161	n=2236	n=410	n=234	n=161
Men	-0.01	0.06	0.00	0.20	0.07	0.02	0.00	0.11
Women	0.04	-0.12	-0.11	-0.12	0.10	-0.15	-0.10	-0.18
Not at work	n=2036	n = 356	n = 210	n = 135				
Men	0.12	-0.07	0.00	0.04				
Women	0.07	0.00	-0.02	-0.03				
				Education in 1981[2]				
At work	n=2725	n=624	n=358	n=239	n=2725	n=624	n=358	n=239
Men	0.16	0.01	0.01	0.06	-0.14	-0.17	-0.19	-0.03
Women	0.22	0.17	0.22	0.00	-0.10	0.02	0.02	0.03
Not at work	n=2507	n = 532	n = 314	n = 198				
Men	-0.04	-0.02	-0.05	0.00				
Women	-0.01	-0.03	-0.04	-0.01				
				35-year BMI change[2]				

At work	n=2678	n=600	n=341	n=233	n=2678	n=600	n=341	n=233
Men	0.20	0.18	0.23	-0.01	0.17	0.20	0.24	0.06
Women	0.11	0.10	0.10	0.15	0.15	0.12	0.10	0.15
Not at work	n=2440	n=506	n=293	n=194				
Men	0.07	0.01	0.07	-0.27				
Women	0.14	0.04	0.04	0.02				

* From the 5232 individuals and 1587 full twin pairs, those with mixed LTPA behavior have been excluded from the analyses.
**Twin pairs concordant for their working status. Correlations calculated for within pair difference in sitting time in 2011 and within pair difference in 35-year leisure-time physical activity (broadly active vs. broadly inactive), education in 1981 or in 35-year BMI change. Point biserial[1] or Pearson[2] correlation coefficients.

DISCUSSION

In this population-based Finnish twin cohort with more than 5000 twin adults (53–67 years of age in 2011), the mean total daily sitting time was 6 hours and 20 minutes, constituting on average 3 hours of sitting at work, which is at the same level with earlier cross-sectional studies [5, 7, 15]. However, the stratification by working status sheds further light on the sitting duration. With the focus on those at work, the results indicate a longer overall sitting time than those not at work. Further, non-work sitting time was 37 minutes longer among men than in women. The results also showed that being long-term physically inactive in leisure-time was associated with longer non-work sitting time, whereas higher education was associated with longer total but shorter non-work sitting times among those still at work. Moreover, an increase in BMI was associated with a longer overall sitting time regardless of working status, and the association was not affected by familial confounding among women.

In earlier studies, those with high LTPA have been reported to sit less compared to inactive persons [5, 6], and this trend was also evident in our study. However, as we had a follow-up over three decades for the long-term LTPA, our results add to earlier findings, mainly based on cross-sectional settings [5-7, 15]. Though long-term physical inactivity was associated with 30 minutes longer non-work sitting time in comparison to those being persistently active, long-term LTPA had only weak associations with total sitting time among those at work.

In this study, each year of higher education was associated with 10 minutes longer total sitting time among participants still at work, supporting earlier findings [14, 15]. However, the association between higher education and non-work sitting time was the opposite; higher education was associated with less non-work sitting. This is in line with earlier studies showing higher education being associated with more LTPA [13], and that physically active adults report less sitting than less active people [5, 6]. This might be useful information from a public health perspective suggesting that those with lower education might benefit of campaigns to increase physical activity instead of decreasing sedentary behavior during their leisure-time [1].

Another novel finding of this longitudinal study is the association between weight gain and sitting time: each one-unit increase in BMI was associated with an increase in total sitting time of about 7 minutes in those at work and about 3 minutes in those not at work. Our findings support earlier studies showing high BMI and obesity being associated with more sitting [12, 17]. The co-twin control analyses provided some evidence that an increase in BMI has an independent association (i.e. not affected by familial confounding) with both total and non-work sitting times among women at work life. Also previous results suggest that prevention of weight gain is relevant for sitting behavior [10, 19] and that weight gain in adults is associated with a lower level of LTPA [9, 18]. Whether the relationship between high BMI and weight gain with a longer sitting time is modified by inactivity remains to be established.

One of the strengths of this study is the use of the co-twin control design, which enables investigating the possible effect of familial confounding on the associations. The results of the differences within twin pairs (stratified for concordance for working status in this study) confirmed the results of the whole cohort, but indicate that familial confounding may play a role in the associations between LTPA, education, BMI (in men), and sitting time as was expected due to known influence of genetics in education, BMI, sedentary behavior, and LTPA [24-26]. However, the strength of the associations between health behaviors, education and sitting time (as indicated by correlation coefficients in the within pair analyses) were weak, the results of the familial confounding should be interpreted with caution. Further strengths of this study are that the Finnish Twin Cohort is representative of the Finnish adult population [29] and that the comprehensive surveys were repeated four times, providing a unique opportunity to follow the same participants over 35 years and to investigate the long-term trends of LTPA and BMI development.

One of the limitations is the self-reported survey data and that covariates were queried in 1981, i.e. 30 years earlier. This may have affected the observed associations. However, we used covariates close to baseline in order to avoid revised causality. Because education is commonly known important modifier of health and health behaviors, we used our covariates from 1981 when the mean age of the participants was 30 years and by which most of them had accomplished their formal education level. Furthermore, we cannot rule out bias due to the social desirability of reporting health behaviors [33, 36, 37]. For example, the underestimation in self-reports of sitting time has been around 20% [5] and adherence to LTPA recommendations has been substantially lower measured with accelerometers than based on self-reports [33, 37]. Therefore, the measurement errors will weaken the found associations. However, previous accelerometer-assessed data also included standing and lying positions because various domains of sitting could not be extracted from such data. Further, various components of non-work sitting cannot be differentiated from accelerometer data even today without a questionnaire. In this study, we had the possibility to study different sitting domains in different combinations. For simplicity, we combined non-work sitting domains as one group. In the literature, working age adults seem to spend one-third to one-half of daily sitting time at work [7, 15], which is in line with our study. However, our survey was limited to the response alternative of four hours or more as the highest alternative for sitting at work. Even though the highest category was coded to five hours of sitting at work, it is likely that the ceiling effect may have affected sitting at work for those working full time in offices or desk-based tasks. Further, sitting while commuting can also be included in work-related sitting [7], and thus comparing task-based sitting between studies and countries can be challenging.

PERSPECTIVE

The results of this study have several public health implications. First, long-term physical inactivity and increase in BMI are associated with longer sitting duration, and thus life-long physical activity should be promoted for all. Various approaches should be used to minimize the health risks related to both weight gain and longer sitting time. New evidence has emerged that participation in LTPA would diminish at least some of the deleterious effects of prolonged sitting [1, 2]. Thus, not only interventions to increase LTPA levels but also to shorten prolonged sitting or diminish sitting in general both at work and non-work should be promoted. Our findings are also in line with earlier studies[38, 39] for the importance to assess domain-specific and relative LTPA including sitting time in further studies.

CONCLUSIONS

Total sitting time in this cohort of 53–67-year-old adults was longer among those still at work. Long-term physical inactivity among those not at work, higher education among those still at work, and weight gain among all were associated with longer total sitting time. Among women at work, an increase in BMI seems to increase sitting independently of familial factors. The difference in total sitting times between those at work and those not at work suggests that wide-ranging public health efforts should be developed to promote life-long LTPA and weight control regardless of working status.

Supplemental Digital Content 1.

Interpretation of the co-twin control design (i.e. within pair analyses)

In this study the within pair analyses has utilized correlations coefficients calculated from the differences within twin pairs (a twin and his/ her co-twin). In within pair analyses we are interested in how the within correlations behave related to the correlation coefficients calculated for the whole cohort (twins treated as individuals). If familial factors play a role, the correlations coefficients between sitting and factors of interest (35-year LTPA behavior, education in 1981, 35-year BMI change) analyzed for the whole cohort would clearly attenuate or change into other direction in analyzing the correlation coefficients related to DZ and MZ pairs. The role of genetics can have a role, if the associations would be about at the same level for the whole cohort and for within DZ twin pairs, but the association would diminish/ change direction in within MZ twin pairs. Lastly, if the associations would remain in the same level for the whole cohort and within MZ and DZ pairs, the finding would suggest independence from familial factors and reflect a somewhat direct association between factor of interest and sitting.

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