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Section: Original Research

Article Title: Long-term Correlates of Objectively Measured Physical Activity and Sedentary Time in Norwegian Men and Women

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Long-term correlates of objectively measured physical activity and sedentary time in Norwegian men and women

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Abstract

Background: Sex, age, body mass index (BMI), perceived health and health behavior are correlates known to affect physical activity and sedentary time. However, studies have often been cross-sectional, and less is known about long-term correlates. Thus, the aims were to investigate 1) the associations between a set of characteristics (demographic, biological, psychological and behavioral) and objectively measured physical activity and sedentary time at 13 year follow-up, and 2) the association between changes in these characteristics over time and physical activity and sedentary time. **Methods:** Baseline characteristics were collected in 40-year-olds in 1996, and follow-up data on objectively measured physical activity and sedentary time were obtained in 2009 (n=240). Data were analyzed by multiple linear regressions. **Results:** Self-reported physical activity ($p<0.001$) and improved perceived health ($p=0.046$) were positively associated with moderate-to-vigorous physical activity (MVPA) whereas BMI ($p=0.034$) and increased BMI ($p=0.014$) were negatively associated with MVPA at follow-up. Women spent less time being sedentary than men ($p=0.019$). Education ($p<0.001$) was positively associated and improved perceived health ($p=0.010$) was negatively associated with sedentary time at follow-up. **Conclusions:** MVPA and sedentary time at follow-up were associated with behavioral, biological and demographic correlates. However, the nature of our analyses prevents us from inferring causality.

Keywords: Accelerometry, health behavior, health

Background

Given the considerable literature supporting the beneficial impact of physical activity for preventing non-communicable diseases,[1-4] it is important that people engage in habitual physical activity. Despite the paucity of objective data on sedentary time from prospective observational studies, recent studies have also suggested that sedentary behavior is a population-wide, ubiquitous health risk independent of leisure-time physical activity.[5-8]

Cross-sectional studies indicate that globally, a substantial proportion of people are insufficiently physically active to maintain good health.[9-12] Understanding why some people are more physically active than others is essential for developing public health interventions aimed at increasing physical activity and decreasing sedentary time.[13] Previous studies have suggested education level,[13-15] health status,[13,14] intention to change behavior,[13,15,16] physical activity earlier in life (tracking),[13-18] sex, body mass index (BMI), smoking,[15,18,19] and psychosocial factors[13] as correlates of physical activity. However, most studies have used cross-sectional designs, and prospective observational studies examining the association between these correlates and objectively measured physical activity and sedentary time are few in number.[13-15,20] Moreover, most previous research has usually considered leisure-time physical activity, which may constitute a small part of overall physical activity.[13,15]

Therefore, this study aimed to extend the existing knowledge by examining 1) the associations between a set of characteristics (demographic, biological, psychological and behavioral) and objectively measured physical activity and sedentary time at 13 year follow-up, and 2) the association between changes in these characteristics over time and physical activity and sedentary time at follow-up.

Methods

Population

This study is based on data from The Age 40-Program organized by the National Health Screening Service in 1996[21] (referred to as baseline) and The Physical Activity among Adults and Older People Study in 2009[22] (referred to as follow-up). Both studies invited all men and women born between 1954 and 1956, age 40–42 at baseline, in three municipalities in the rural county Sogn & Fjordane in the western part of Norway (N=565 at baseline and 543 at follow-up).[21,22] At follow-up, participants (age 53–55) were asked to provide consent to link their data to their previously collected baseline data. We included all participants with valid data at both baseline and follow-up, which in total yielded 240 eligible participants (52% of the original sample; 44% men). An overview of the participants is displayed in Figure 1. The study was approved by the Regional Committee for Medical Research Ethics, the Norwegian Social Science Data Services AS and the Norwegian Tax Department. The Norwegian Institute of Public Health gave their approval to use the data from The Age 40- Program.

Baseline measurements

At baseline, height and weight were measured according to standardized procedures to the nearest cm and 0.5 kg, respectively.[23,24] BMI was calculated as participants' weight divided by their height squared (kg/m^2). Perceived health, musculoskeletal pain and stiffness, psychological complaints, intention to improve diet and increase physical activity, smoking habits, physical activity and education level were assessed by self-report, as previously described.[21,25] The instruments have been used in population based screening programs since the 1970s and discriminate well.[25] The use of standardized and unchanged procedures and methods have been emphasized to ensure comparability between cohorts.[26] Physical activity was assessed using the Cohort of Norway (CONOR) instrument, which asked for a weekly average of physical activity during leisure-time over the last year. The duration was quantified on a four-category scale (none, < 1 h, 1–2 h and ≥3 h per week) for light activity (not sweating/not out of breath) and vigorous physical activity (sweating/out of breath).[27,28] For this study, physical activity was categorized into 1) light (any duration of light physical activity or <1 hour of vigorous physical activity per week), 2) moderate (1–2 hours of vigorous physical activity per week) and 3) vigorous physical activity (3 or more hours of vigorous activity per week). Highest completed education level was assessed with a five-category scale[21] and later collapsed into the following categories: 1) less than high school, 2) high school, 3) college or university <4 years and 4) college or university ≥4 years. Descriptions of the various baseline characteristics are displayed in Table 1.

Follow-up measurements

At follow-up in 2009, physical activity level was measured objectively with the ActiGraph GT1M accelerometer (ActiGraph, LLC, Pensacola, Florida, USA). The participants were instructed to wear the monitor above the right hip during all waking hours for seven consecutive days, except during water activities and showering. A SAS-based software program (SAS-Institute Inc, Cary, North Carolina, USA) called CSA Analyzer (csa.svenssonspork.dk) was used for data reduction. Epoch length was set to 10 seconds and later collapsed into 60-second epochs for comparisons with other studies. All night activity (between 00:00 and 06:00) and all sequences of at least 60 minutes of consecutive zero counts, with allowance for interruptions of 1–2 minutes of counts above zero, were excluded from each individual's recording. Participants with valid wear time of at least 10 hours for at least four days were included in further analyses. Accelerometer data were summarized as time spent per day in moderate-to-vigorous physical activity (MVPA, counts per minute (cpm) ≥2020) and sedentary time (cpm <100).[29] Additionally, perceived health, education level, smoking habits and physical activity were self-reported using the same questionnaire as the one used for the baseline data. At follow-up, height and weight were both measured and self-reported for approximately 33% of the participants and only self-reported for the remaining sample. For those who provided both self-reported and measured BMI at follow-up, the Bland Altman plot showed individual differences (95%

limits of agreement: -3.28, 1. 98 (intraclass correlation (ICC) =0.952) for women and -2.28, 2.14 (ICC=0.953) for men). The mean difference (standard deviation, SD) between self-reported and measured BMI was -0.65 (1.34) kg/m^2 ($p<0.001$) for women and -0.07 (1.13) kg/m^2 ($p=0.604$) for men. Adjusting for the measurement method yielded results similar to those for the non-adjusted associations (data not shown).

Change in the characteristics from baseline to follow-up in BMI, perceived health, smoking and education level were calculated and is presented in Table 1.

Statistics

Participants' characteristics combined and stratified by sex (where applicable) are presented as mean and SD or numbers and proportion. Student's t-test for independent groups (for continuous variables) and chi-square tests (for proportions) were employed to identify any differences between sexes and between participants and drop-outs. Multiple linear regression analyses were performed to assess any associations between a set of characteristics (sex, baseline BMI, perceived health, musculoskeletal pain and stiffness, psychological complaints, intention to improve diet or increase physical activity level, smoking, self-reported physical activity and changes in BMI, perceived health, smoking and education level), which were the independent variables, and objectively measured MVPA and sedentary time at follow-up, the dependent variables. Preliminary analyses were conducted to ensure that there was no violation of the assumptions of linear regression. Based on literature and theoretical knowledge, all variables were included in a full model. Because of the high correlations between the psychological complaint variables, a latent variable was created using categorical principal component analysis.[30] Lower scores indicated better mental health. Results are presented as regression coefficients (β), 95% confidence intervals (CI) and p-values. Linearity between the independent and dependent variables was assessed prior to performing the analyses. The residuals were normally distributed in both models. We found no sex-specific associations (results not shown), and results are therefore presented combined and adjusted for sex. A Bland

Altman plot[31] and ICC were used to test the agreement between the anthropometric measurement methods. All statistical analyses were performed using the IBM Statistical Package for the Social Sciences (IBM SPSS) version 20.0 (IBM Corporation, Somers, NY, USA).

Results

Baseline data

Descriptive baseline data are displayed in Table 2. Significantly more men (62%) than women (39%) were overweight or obese (BMI $\geq$25 kg/m^2) (p=0.003). In total, 89% of the participants reported their health to be good or very good, whereas 24% of the participants reported musculoskeletal pain and stiffness, with no significant differences between men and women. In total, 53% reported the intention to improve their diets (no significant differences between sexes), but significantly more women (74%) than men (61%) reported the intention to increase their physical activity levels (p=0.030). Twenty percent of the participants were smokers. In total, the majority (63%) reported education levels in the two lowest groups (i.e., completed high-school or less). Approximately 46% reported moderate to vigorous activity levels at baseline. Men reported significantly higher levels of physical activity than did women (p=0.006).

Follow-up data and changes over time

At follow-up, the mean BMI was 26.8 (3.9) kg/m^2 for men and 25.2 (3.9) kg/m^2 for women (p<0.001). Consistent with the baseline findings, significantly more men (66%) than women (48%) were overweight or obese (p=0.021). Men spent significantly more time sedentary than did women (546.0 (87.3) min/day vs. 511.5 (82.9) min/day, p=0.002). However, no significant sex difference (p=0.454) was found for time spent in MVPA (43.4 (25.3) min/day for both sexes). Between baseline and follow-up (Table 2), BMI increased by 0.8 kg/m^2 (men and women combined), 14% of participants reported improvement in perceived health and 8% had quit smoking. Significantly more women (p=0.019) had increased their education levels compared with men (18% vs. 7%).

Long-term associations with MVPA and sedentary time

Self-reported physical activity at baseline (β 8.79, p<0.001) and improved perceived health from baseline to follow-up (β 6.09, p=0.046) were positively associated with MVPA at follow-up in a graded manner (Table 3). Each unit of difference BMI at baseline (β -1.00, p=0.034) and each unit of increase in BMI from baseline to follow-up (β -1.94, p=0.014) were negatively associated with MVPA at follow-up (Table 3). Sex was associated with sedentary time at follow-up as women spent less time being sedentary than did men (β -28.76, p=0.019). Educational level at baseline was positively associated with time spent sedentary at follow-up in a graded manner (β 27.29, p<0.001), whereas improved perceived health from baseline to follow-up was negatively and graded associated with time spent sedentary at follow-up (β -27.18, p=0.010) (Table 4). The correlates explained 15.7% and 12.9% of the variance in MVPA and sedentary time, respectively.

Discussion

The results from the present study, which comprised 240 Norwegian men and women who were followed after 13 years, suggest that higher self-reported physical activity levels and lower BMI at baseline and less increase in BMI and improvement in perceived health from baseline to follow-up were associated with more time spent in MVPA at follow-up. Moreover, being a man, higher education level at baseline and perceived worsening in health from baseline to follow-up were associated with more time spent sedentary at follow-up.

Physical activity levels appear to remain stable within groups over time, as determined by what is typically referred to as tracking.[13-17] Studies based on both self-reported[18] and objectively measured[14] physical activity have found an association between physical activity earlier in life and levels of physical activity later in life. Although most studies report low to moderate tracking of physical activity,[16,18,32] the importance of establishing health-enhancing behaviors such as physical activity early in life has been emphasized.[17] However, the differences between studies on how physical activity is assessed and categorized are considerable, which hinders interpretation and comparison between studies. Our finding corroborate and partly extend these previous studies by suggesting that previously self-reported physical activity is associated with later levels of objectively measured physical activity.

We also observed that both lower baseline BMI and less increase in BMI were associated with higher physical activity later in life, consistent with some[14,15] but not all[18] previous observations. The association between BMI and physical activity is most likely bidirectional because habitual physical activity across the life course is associated with lower weight gain[33] but obesity is also a determinant of lower levels of physical activity.[14] We did not observe any association between perceived health at baseline and physical activity, as previously reported.[14,18] This may be explained by the differences in participant ages between the study populations and different measures of physical activity and perceived health.[14,18] Nevertheless, we observed that improved perceived health from baseline to follow-up was associated with both an increase in physical activity and a decrease in time spent sedentary. Thus, present perceived health seems more important for PA than perceived health in the past.

Although education level has been found to be positively associated with physical activity,[13-15] the association has not been consistent in prospective studies,[34] which corroborates our observations. Contrary to previous observations,[14,18] we found a positive association between education level and time spent sedentary. Other studies[14] that also employed an objective measure of sedentary time found that participants with higher education levels compared with those with the lowest levels recorded 42 min/day less sedentary time. Kirjonen et al[18] suggested that limited education was associated with an increased probability of remaining sedentary. Differences between studies may be explained by differences in the study populations. For example, Hamer et al[14] examined these associations in a healthy, fairly homogeneous sample that was participating in the Whitehall study, whereas our participants were living in rural Norway. Generally, it is likely that individuals with higher education levels may tend to have sedentary desk-based work, which may contribute to their higher overall time spent being sedentary.

Our observation suggesting more sedentary time among men compared with women corroborates previous observations that used objective measures of sedentary time.[10,12] We could hypothesis that differences in education level could explain this association; however, no significant difference in education level was observed between the sexes at baseline or follow-up. Several[10,15] but not all[12] studies that used either self-reported or objectively measured physical activity have found more time spent in MVPA among men compared with women. We did not observe a sex difference in MVPA. In contrast with other studies,[13-16,19] we also did not observe any significant associations between MVPA and sedentary time and intention to change behavior, smoking or psychological factors.

Our participants spent less time sedentary and had accumulated more MVPA at follow-up compared with Norwegian, Swedish and US population data.[10,11] Higher levels of physical activity and less time spent sedentary have been observed in those living in this specific area of western Norway for decades.[35] Although this population still appears to be more physically active and less sedentary than other population groups, it is unlikely that this difference in activity levels substantially affected the observed associations between the correlates and the outcomes.

Strengths and limitations

This study's strengths include the 13-year follow-up in the prospective design and the objective assessment of physical activity and sedentary time at follow-up. Objective measurements of physical activity provide more detailed information on time spent in MVPA and sedentary time and are less prone to bias attributable to misreporting or social desirability compared with self-reported physical activity levels.[20]

However, some limitations need to be taken into account when interpreting these results. First, the lack of objective measures of physical activity at baseline, which limited our analyses, prevents us from inferring causality based on our observations. The correlates included in our models only explained a small proportion of the variance in MVPA (16%) and sedentary time (13%) at follow-up. Self-reported exposure variables may be prone to misconceptions and measurement errors, which may have attenuated the observed associations.[36] For example, the association between objectively measured MVPA and self-reported physical activity at follow-up was weak, although it did agree with many previous observations (ρ=0.27, R^2=0.07).[37-39] Additionally, limitations associated with measuring physical activity levels and sedentary time by accelerometry should be acknowledged. For example, accelerometry has known limitations in assessing physical activity during specific types of activities and in assessing sedentary time, and challenges regarding data reduction do exist.[40,41] The variation in wear time is also a limitation when interpreting the data. However, using the percentages of MVPA time and sedentary time as the outcome variables did not materially change our findings. Nearly half of our baseline sample (48%) was lost to follow-up. Dropout analysis showed that nonparticipants at follow-up were more likely to be men (p=0.036) and smokers (p<0.001) and to have higher BMIs (p=0.012) and lower physical activity levels (p=0.003) at baseline. The loss to follow-up could be a source to selection bias. Thus, our results should be interpreted with this in mind. Finally, a number of correlates from multiple domains have been suggested as being associated with physical activity levels and sedentary time in adults.[13] This study only included a limited number of these correlates and domains. It is recommended that future studies include objective measures of physical activity and sedentary time at baseline and follow-up to avoid the measurement errors associated with self-reports, information on physical activity in different contexts and a broad range of correlates from multiple domains.

Conclusions

Our results suggest that higher baseline levels of physical activity, lower baseline BMIs, less increase in BMIs and improved perceived health were associated with increased time spent in MVPA 13 years later. Being female, having lower baseline education levels and improved perceived health were associated with decreased time spent sedentary. However, the correlates included in the present study only explained 16% and 13% of the variance in MVPA and sedentary time, respectively, and the results should therefore be interpreted with caution.

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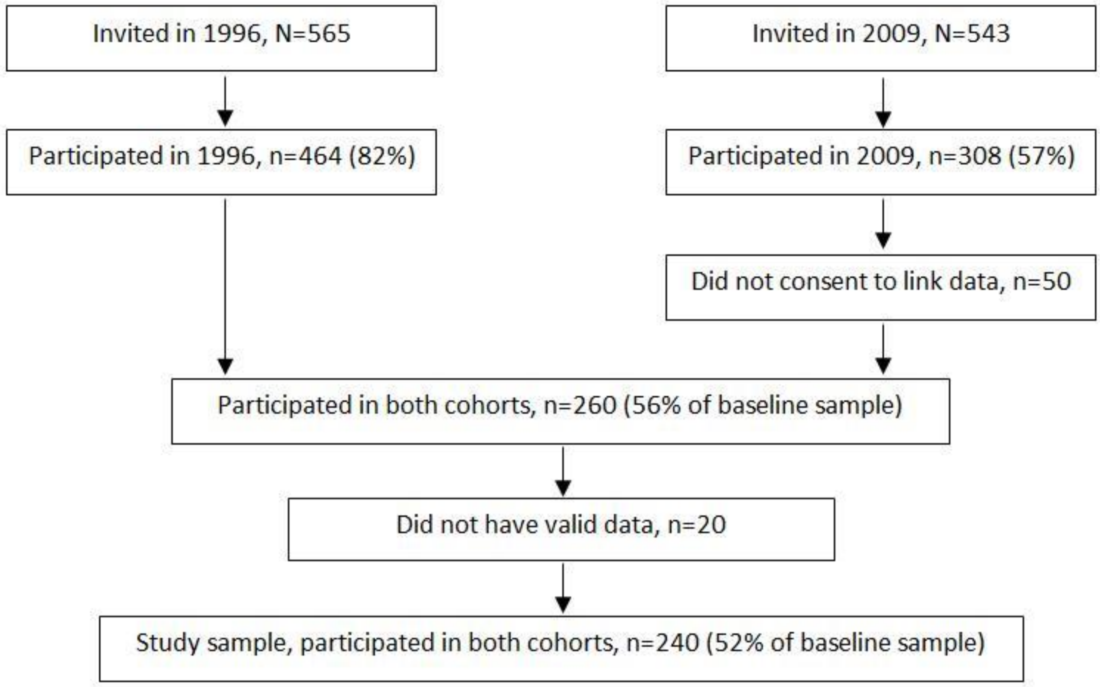

Figure 1. Overview of the study population.

Table 1. Descriptions of baseline characteristics and change in characteristics from baseline to follow-up.

Characteristics	**Instrument**	**Scoring**
BMI	Measured	Kg/m^2
Perceived health	What is your current health status?	1) Poor/Not so good 2) Good 3) Very good
Musculoskeletal pain and stiffness	Have you during the last year suffered from pain and/or stiffness in muscles and joints that has lasted for at least three months?	Yes/No
Psychological complaints	Latent variable on psychological complaints during the last two weeks	Continuous arbitrary unit
Intention to change behavior	During the last 12 months and/or in the next five years, have you attempted to or do you want to: Improve diet Increase physical activity	Yes/No
Smoking	Do you smoke daily?	Yes/No
Physical activity	How has your physical activity during leisure-time been over the last year?	1) Light physical activity 2) Moderate physical activity 3) Vigorous physical activity
Educational level	What is the highest level of	1) Less than high school

Characteristics	**Instrument**	**Scoring**
	education you have completed?	2) High school
		3) College or university <4yrs
		4) College or university ≥4yrs
Δ BMI		Kg/m^2
Δ perceived health		1) Perceived improvement
		2) No change
		3) Perceived worsening
Δ smoking		1) Quit smoking
		2) Never smoked
		3) Still smoke
		4) Began smoking
Δ education level		1) No change
		2) Increased education level

BMI, body mass index; Δ, change from 1996 to 2009

Table 2. Baseline characteristics and change in characteristics, in total and stratified by sex, mean (standard deviation) or number (%).

	All (n=240)	Men (n=105)	Women (n= 135)	p-value for sex difference
Baseline				
BMI (kg/m^2)	25.2 (3.8)	26.3 (3.5)	24.3 (3.7)	<0.001
Perceived health, n (%)				0.522
Poor or not so good	26 (10.8)	14 (13.3)	12 (8.9)	
Good	160 (66.7)	69 (65.7)	91 (67.4)	
Very good	54 (22.5)	22 (21.0)	32 (23.7)	
Musculoskeletal pain and stiffness, n (%)	57 (23.8)	26 (24.8)	31 (23.0)	0.745
Psychological complaints (arbitrary unit)	0.02 (1.02)	0.03 (1.22)	0.004 (0.845)	0.838
Intention to change during the last 12 months or in the next five years, n (%)				
Intention to improve diet	127 (52.9)	52 (49.5)	75 (55.6)	0.353
Intention to increase physical activity	164 (68.3)	64 (61.0)	100 (74.1)	0.030
Smoking, n (%)	48 (20.0)	27 (25.7)	21 (15.6)	0.051
Highest completed education level, n (%)				0.365
Less than high school	122 (50.8)	55 (52.4)	67 (49.6)	
High school	28 (11.7)	8 (7.6)	20 (14.8)	
College or university <4yrs	47 (19.6)	21 (20.0)	26 (19.3)	
College or university ≥4yrs	43 (17.9)	21 (20.0)	22 (16.3)	
Self-reported physical activity, n (%)				0.006
Light	129 (54.0)	50 (48.1)	79 (58.5)	
Moderate	82 (34.3)	34 (32.7)	48 (35.6)	
Vigorous	28 (11.7)	20 (19.2)	8 (5.9)	
Change from baseline to follow-up				
Δ BMI (kg/m^2)	0.8 (2.1)	0.6 (2.0)	0.9 (2.2)	0.369
Δ Perceived health, n (%)				0.215
Perceived improvement	33 (13.8)	18 (17.3)	15 (11.1)	
No change	145 (60.7)	57 (54.8)	88 (65.2)	
Perceived worsening	61 (25.5)	29 (27.9)	32 (23.7)	
Δ Smoking, n (%)				0.189
Quit smoking	18 (7.6)	11 (10.7)	7 (5.2)	
Never smoked	185 (78.1)	77 (74.8)	108 (80.6)	
Still smoke	28 (11.8)	14 (13.6)	14 (10.4)	
Began smoking	6 (2.5)	1 (1.0)	5 (3.7)	
Δ Education level, n (%)				0.019
No change	200 (87.0)	92 (92.9)	108 (82.4)	
Increased education level	30 (12.0)	7 (7.1)	23 (17.6)	

BMI, body mass index; Δ, change from 1996 to 2009

Table 3. Long-term associations of moderate-to-vigorous physical activity (MVPA) (min/day).

	MVPA (min/day)			
	β	**p-value**	**95% CI**	**R^{2a}**
				0.157
BMI (kg/m^2)	-1.00	0.034	(-1.91,-0.08)	
Self-reported PA	8.79	<0.001	(4.07,13.51)	
Δ BMI	-1.94	0.014	(-3.47,-0.40)	
Δ Perceived health	6.09	0.046	(0.12,12.06)	

[a] Adjusted

β, regression coefficient; BMI, body mass index; PA, physical activity; Δ, change from 1996 to 2009

Table 4. Long-term associations of sedentary time (SED) (min/day).

	SED (min/day)			
	β	**p-value**	**95% CI**	**R^{2a}**
				0.129
Sex	-28.76	0.019	(-52.77,-4.75)	
Education level	27.29	<0.001	(17.58,37.00)	
Δ Perceived health	-27.18	0.010	(-47.90,-6.46)	

[a] Adjusted

β, regression coefficient; Δ, change from 1996 to 2009