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Chronotypes and Objectively Measured Physical Activity and Sedentary Time at Midlife

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Abstract

Morning, day or evening chronotypes differ by the circadian timing of alertness and the preferred timing of sleep. It has been suggested that evening chronotype is associated with low physical activity (PA) and high sedentary time (SED). Our aim was to investigate whether such an association is confirmed by objectively measured PA and SED. In 46-year follow-up of the Northern Finland Birth Cohort 1966 study, total PA (MET min/day) and SED (min/day) among 5156 participants were determined using wrist-worn accelerometers for 14 days. We used the shortened Morningness-Eveningness Questionnaire to define participants' chronotypes. As covariates, we used self-reported physical strenuousness of work, health, and demographics, and clinical measures. We used adjusted general linear models (B coefficients with 95% confidence intervals, CI) to analyze how chronotype was related to total PA or SED. As compared to evening chronotype, men with day and morning chronotypes had higher total PA volumes (adjusted B 75.2, 95% CI [8.1, 142.4], p = 0.028, and 98.6, [30.2, 167.1], p = 0.005). Men with day and morning chronotypes had less SED (−35.8, [−53.8, 17.8], p < 0.0001, and −38.6, [−56.9, −20.2], p < 0.0001). Among women, morning chronotype was associated with higher total PA (57.8, [10.5, 105.0], p = 0.017), whereas no association between chronotype and SED emerged. Evening chronotype was associated with low objectively measured PA in both sexes and with high SED in men, even after adjustments for established potential confounders. Chronotype should be considered in PA promotion.

Keywords: chronotype, circadian rhythm, physical activity, occupational physical activity, accelerometer, middle-aged, sedentariness

Introduction

Low physical activity (PA) is a global pandemic, contributing to a mortality burden as large as tobacco smoking. It is responsible for more than 5 million deaths per year and is one of the United Nations' primary targets to reduce noncommunicable diseases.[1] Previous studies also suggest that prolonged sedentary time (SED), meaning low energy expenditure activity in a sitting or reclining posture,[2] including sitting time at work, in transit, and in leisure time,[3] is associated with increased risk for developing overweight, obesity, and chronic diseases.[4-6] Moreover, high PA has been shown effective in improvement in sleep quality.[7]

An individual's chronotype is reflected in the variations in circadian preferences of daily sleep, wake, and high alertness timing. A common chronotype classification method in studies divides people into the categories of morning type (M-type), evening type (E-type), or day type (D-type), which falls between the first two. According to the type, the peak of potential performance and alertness occurs earlier among M-types and later among E-types.[8]

Recent studies have suggested that E-type is associated with higher morbidity.[9-11] Similarly, survey-based studies indicate that E-type associates with significantly lower levels of PA[10,12] and more time spent sitting as compared to M-types.[10] The higher morbidity associated with E-type may partly be explained by the cumulating unhealthy sedentary and dietary habits, comprising sleep, smoking, and excessive alcohol consumption. A deeper understanding of the different chronotypes and their associations with PA and sedentary behavior is needed to develop practical applications and recommendations at population level and for subpopulations at risk.

Few epidemiological studies have investigated the effect of chronotype on PA and SED simultaneously.[8] In addition, few epidemiological studies have examined such differences using objectively measured PA and SED data. The aim of this study was to investigate the association between chronotype and accelerometer-based PA and SED in middle age. We hypothesized that individuals' chronotype is associated with PA and SED, M- and D-types associating with higher physical activity and lower SED compared to E-type.

Material and Methods

Participants

The mothers of children whose expected date of birth fell between January 1 and December 31, 1966, in Northern Finland were invited to participate in the NFBC1966 study, and 12 058 children were born in the cohort (96% of all births in 1966 in the region).[13] Questionnaires, clinical examinations, and health care records have since been collected regularly about these individuals. Personal identity information was encrypted and replaced with identification codes to provide full anonymity. The 46-year follow-up study was approved by the Ethical Committee of the Northern Ostrobothnia Hospital District in Oulu, Finland (94/2011). The subjects and their parents provided written consent for the 1966 study. This study analyzed survey-based and clinical data collected as part of the 46-year follow-up, targeting the cohort members who were alive and living in Finland (n = 10 321), as shown in Fig. 1.

[insert Figure 1]

Physical activity and sedentary behavior

Participants attending the clinical examinations of the 46-year follow-up were invited to participate in measurements of PA using waterproof wrist-worn Polar Active accelerometers (Polar Electro Oy, Kempele, Finland).[14,15] Participants were asked to wear the monitor 24 hours per day for at least 14 days, also while sleeping, on their nondominant wrists. The day on which the participant received the activity monitor was excluded from the analysis. Participants with at least four valid days were included in the analyses, and daily averages of duration spent in five activity levels (min/day) were calculated.[16] Criteria for a valid day were defined as at least 600 min/day (without considering them being consecutive minutes) monitoring time during waking hours.[17,18] Valid days did not need to be consecutive days of the 14-day period. Distribution for the number of valid days and the monitoring time during waking hours in a valid day included in the analyses are presented in Supplementary Table 1. The accelerometer user interface was blinded, so it did not provide feedback to the user.

The accelerometer provides daily PA based on estimated metabolic equivalent (MET) values for every half minute using background information (body height, body weight, age, and sex).[19] Polar Active has been shown to correlate well with the doubly labeled water technique of assessing energy expenditure during daily living (R^2 = 0.78), and moderately well with added strength and bike ergometer training (R^2 = 0.62).[14] Measured PA was distributed over five levels (*very light*: 1–1.99 MET, *light*: 2–3.49 MET, *moderate*: 3.50–4.99 MET, *vigorous*: 5–7.99 MET, and *very vigorous*: ≥ 8 MET) based on the thresholds used by the manufacturer.[20]

Very light activity between 1 and 1.99 METs was classified as sedentary time (SED, min/day). In comparison with various accelerometry-based methods, the threshold < 2 MET for Polar Active provided similar results as threshold < 100 counts per minute (cpm) for ActiGraph, and the mean difference between methods was 7.0 min/day (95% confidence interval from −17.8 to 31.7 min/day).[21] Total PA volume including all activity performed with intensity of 2 METs or higher was calculated by multiplying each MET value with its duration (total PA, MET min/day).[16]

Activity measurements were performed between April 2012 and February 2014. It has been shown that the proportion of time and intensity spent in PA vary significantly over the seasons.[22] For this reason, we categorized the PA collection date into two categories using the spring and autumn equinoxes as cutoffs (summer/winter). The final study population included those participants whose data on the studied variables at 46 years were available (n = 5156).

Chronotyping

In our study we used the shortened version of the Morningness–Eveningness Questionnaire (MEQ), which is one of the most widely used and accepted instruments to measure chronotype and has been reported to be a useful tool for assessing chronotype.[23] Scores on the shortened MEQ range from 5 to 27, and the sum score is grouped into three chronotypes: 5–12 as E-type, 13–18 as D-type, and 19–27 as M-type.[24] The MEQ-questionnaire comprises six questions asking preferred time of rising and bedtime, as well as physical and mental performance and alertness after rising and after different hypothetical activities, for example, “You have decided to engage in some physical exercise. A friend suggests that you do this for one hour twice a week, and the best time for him/her is between 7:00 and 8:00 a.m. Bearing in mind nothing but your own internal ‘clock,’ how do you think you would perform?”[25]

Confounding variables

A postal survey enquiring about the participant's health status, social background, lifestyle, and work was conducted between 2012 and 2014. The participants who were employed answered the question "To what extent are the following tasks and postures part of your job?", and the response scale was from 5 (*very often*) to 1 (*not at all or very rarely*). The question included nine items: "Heavy physical work in which the body has to struggle," "Lifting loads of 1 to 15 kg," "Lifting loads over 15 kg," "Continuous movement or walking," "Repetitious work movements," "Standing," "Working with the upper arms elevated," "Forward-bent work postures," and "Rotational movements of the trunk." We reclassified the scale as physically light work (*light work*, 1–2) and strenuous work (*strenuous work*, 3–5). The sum of the recoded answers of nine items was divided into strenuous or light work using the medians as cutoffs.[26]

Smoking status (nonsmoker or former smoker, current smoker) and alcohol consumption (g/day) were determined based on multiple questions about smoking and drinking habits. Heavy users of alcohol were defined according to the instructions of the Finnish Health Authority alcohol consumption, which sets the level for men at ≥ 40 g/day and women at ≥ 20 g/day. In addition, we enquired about each participant's education, marital status, and prevalence of diagnosed diseases.

All participants were invited to a clinical examination, and 5,862 (56.8%) attended. Trained nurses assessed the participants' medical condition, height, weight, and waist circumference, and body mass index (BMI, kg/m^2) was calculated.

Statistical analysis

Since distributions of both chronotypes and strenuousness of work are known to differ between men and women, all analyses were conducted stratified by sex. Total objectively measured PA volume was recoded according to tertiles as follows: low total PA (men 152.3–956.9 MET min/day; women 164.6–927.8 MET min/day), medium total PA (men 957.0–1227.7 MET min/day; women 927.9– 1170.6 MET min/day) and high total PA (men 1227.8–3382.2 MET min/day; women 1170.7–2733.0 MET min/day). The distributions of chronotype, physical strenuousness of the work (light/strenuous), smoking status (no or former smoker/current smoker), heavy alcohol consumption (men ≥ 40 g/day; women ≥ 20 g/day), education (basic or secondary/higher education), marital status (living alone/cohabiting or married), prevalence of diagnosed diseases (cardiovascular disease, diabetes mellitus, cancer, musculoskeletal diseases, mental disorder, and thyroid disease; no/>1), body mass index (BMI), waist measurement (WC), and seasonal PA collection time (summer/winter) were calculated within each tertile group, and the statistical significance of the differences in these were tested using the χ^2 test. Similarly, descriptive information of the three chronotype classes were tested using χ^2 test.

To reveal the significant determinants of PA and SED volume, univariate associations between total PA, SED, and potential confounders were first analyzed using the independent-samples t-test, with Tukey post-hoc tests for normally distributed variables and with the Kruskal–Wallis test for skewed data. All variables significantly associated with total PA and SED in univariate analyses were entered in the general linear model analysis using enter –method. The physical strenuousness of the work, smoking status, heavy alcohol consumption, marital status, prevalence of diagnoses, BMI, and seasonal PA collection time were treated in the models as potential confounding variables. Education had a strong negative relationship to the physical strenuousness of work, and the variable was therefore excluded from our general linear model analyses. The Bonferroni post-hoc comparison was applied to compare the three chronotypes. Statistical significance was set to $p < 0.05$, and statistical analyses were performed with IBM SPSS Statistics for Windows, version 24.0 (IBM Corp., Armonk, USA).

Results

More than half of the study population were D-types (55.5% men and 51.8% women). In women, the proportions of M-types (42.0%) and E-types (6.2%) were slightly higher than in men (38.9% M-types; 5.7% E-types). Table 1 shows the characteristics of the study participants (n = 5156) across the total PA tertiles. There was a significant difference in the prevalence of different chronotypes across the total PA tertiles in both sexes. The frequency of E-type individuals was highest among those with low total PA volume. In women, the significant difference in the distribution of D-types across the total PA volume categories appeared between medium (54.2 %) and high PA (47.8 %) tertiles ($p < 0.05$).

In both sexes, participants in the low PA volume category had higher mean total SED than those in the medium or high PA volume categories (post-hoc analyses, all $p < 0.0001$). There was a significant inverse association between education and total PA volume. Physical strenuousness of the work was positively associated with the volume of PA both in men and women. Heavy alcohol consumption was related with men's total PA.

[insert Table 1]

The characteristics of the three chronotypes are presented in Table 2. Total PA and SED levels were significantly different between the chronotypes, with the M-type participants having higher amount of total PA and lower SED, and D-type men lower daily SED compared to E-type subjects. In men, education and physical strenuousness of the work were significantly associated with the chronotype. In women, highest prevalence of smokers and heavy alcohol users were observed among those with E-chronotype.

[insert Table 2]

The final general linear models explained 12.4% of the variance in total PA volume and 14.6% of the variance in total SED in men, and 12.7% of the total PA variance and 18.2% of the SED variance in women. Tables 3 and 4 show the statistically significant correlates of the total time spent in PA (MET min/d) and SED according to general linear model analyses.

Chronotype was positively associated with total volume of PA both in men and women when adjusted for all potential confounders (men $p = 0.014$; women $p = 0.002$). Significant differences in post-hoc comparison between E-type and M-type individuals emerged. When referring to E-type subjects, M-type men had 98.6 (95% CI [30.2, 167.1]) MET min/day higher total daily PA volume ($p = 0.005$), and M-type women had 57.8 (95% CI [10.5, 105.0]) MET min/day higher volume of total PA ($p = 0.017$). Post hoc analyses revealed that also D-types had significantly higher levels of PA compared to E-types in men but not in women. However, there was a nonsignificant linear trend across the chronotypes in women's total volume PA.(Table 3)

[insert Table 3]

In general linear model analysis in men, a positive relationship between chronotype and SED was found. According to post-hoc comparisons, M-type and D-type subjects had significantly higher total time spent sedentary compared to E-type participants. When referring to E-type subjects, M-type subjects had 38.6 (95% CI [–56.9, –20.2]) min/day less SED ($p < 0.0001$), and D-type subjects 35.8 (95% CI [–53.8, –17.8]) min/day less. In women, chronotype was not significantly associated with the total time spent sedentary ($p = 0.257$).(Table 4)

[insert Table 4]

The physical strenuousness of the work was the most significant determinant in the general linear models in both sexes (both $p< 0.0001$). Compared to the subjects engaging in light work, subjects with physically strenuous work had significantly higher levels of total PA and lower levels of SED. Those with physically strenuous work had 193 MET min/day higher total PA volume and 61 min/day less SED compared to those having lighter work in men, and 151 MET min/day higher total PA volume and 62 min less SED in women, respectively.

Discussion

This is the first population-based study investigating the effect of chronotype on PA and SED simultaneously using objectively measured PA and SED. The results showed that the evening chronotype is associated with low objectively measured total PA volume in both sexes and high SED in men in middle age. In this study, when referring to E-type subjects, M-type subjects had significantly higher total daily PA volume in both sexes, and significantly lower time spent on sedentary behaviors in men. In addition, D-type men had significantly higher total daily PA volume and lower time spent on sedentary behaviors when referring to E-type subjects.

Our findings are in line with earlier survey-based studies using different kinds of chronotyping. Wennman and colleagues[10] divided their study population (n = 4904) into five chronotype groups: rested more-evening type (28%), rested more-morning type (24%), morning type (23%), tired more evening type (17%) and evening type (8%) groups. Self-reported PA was categorized into three categories (none to very low PA, low PA, and medium PA) and self-reported sitting time was categorized in two categories (medium and high sitting time). Evening type and the tired more evening type had higher odds of low PA compared to morning type. In addition, evening type was associated with higher odds of more time spent sitting compared to morning type. Shechter and colleagues[12] divided participants (n = 22) categorically into those having lower MEQ scores and those having higher MEQ scores by median split. Higher MEQ group (M-types) were found to have spent a significantly higher percentage of time in moderate to vigorous PA (MVPA) compared to those in the lower MEQ group (E-types).

Previously it was showed that men spend more minutes in moderate-to-vigorous PA and sedentary time compared with women.[27] It was also suggested that women may naturally spend more time doing light household activities than men. In the present study, men's mean total PA volume was significantly higher than in women. Additionally, accelerometry measured SED was higher in men, which supports also the recent findings among Finnish adults.[17] Based on our results, E-type men were the most sedentary. After adjustments, we found that the mean daily proportion of SED was over 30 minutes higher in E-type men than D- or M-type men. The volume of total PA collected during waking hours were significantly lower not only among E-type men subjects, but also among D-type men subjects compared to M-type men. Higher SED among E-types has been discussed to be due to E-types spending time sitting particularly in the evenings when others are already asleep.[10] E-types temporal patterns of daily activities, high alertness timing, and sleep rhythm may not fit into the schedule of the surrounding society as swimmingly as other chronotypes' patterns. In addition to the beneficial effects of high PA on sleep quality[7], previous study suggested that sleep disturbances could impair a person's capacity for exercise.[28] Taken together, the association between chronotype and PA and SED in middle age appeared to be stronger among men than women in our study. Future studies are needed to clarify this relationship more specifically. Previous large-scale population studies have considered sex as a confounding factor and have not analyzed the results separately for men and women.[9,10]

Based on our results, physical strenuousness of the work was the most important determinant of PA and SED. However, a significant association between chronotype and total PA remained even after adjustment for the physical strenuousness of the work and other confounding factors. Nevertheless, recent research showing potentially differing cardiovascular and metabolic health effects of leisure-time PA as compared to occupational PA[29] emphasizes the relevance of considering physical strenuousness of work in our design. In an earlier cross-sectional study, Van Domelon et al. investigated the relationships between job type (active or sedentary) and objectively measured daily PA levels in 1826 American adults aged 20–60 years. They showed that in full-time workers, those with active jobs had greater weekday activity than those with sedentary jobs (22% greater in men; 30% greater in women).[30]

Closely related to occupations, overall socioeconomic status has been found to be associated positively with leisure time PA and negatively with occupational PA.[31] This was observed also in our study population, as the highest PA tertile included considerably less highly educated participants than the other tertiles. This might be due to highly educated having more sedentary work. In our study, education had a strong negative relationship to physical strenuousness of the work and was therefore excluded from our general linear model analyses to avoid over-adjustment.

Further strengths of this study include a large population-based sample and the objective measurements of SED and PA, with a high compliance of participants wearing the activity monitor. Accelerometers were blinded with no feedback to the users. In the analyses, we included the whole spectrum of activities, from very light to vigorous PA. Women are typically earlier chronotypes than men, but the difference weakens over the years after 40.[32] In our study, we conducted all our analyses stratified by sex. Consequently, we found clear sex differences in association between chronotype and PA and SED. The workload of women's and men's occupations differs, and there are also differences in leisure-time and housework profiles. Yet these profiles in Finnish society are not directly generalizable to other societies and cultures.

The methodological limitations of accelerometer measurement of PA and SED should be acknowledged. Objective measurement by wrist-worn device does not capture all types of PA precisely, underestimating, for example, cycling and carrying loads, or does not recognize the body posture in the SED measurement.[14,33] Accelerometer data give an overall picture of the monitor user's activity and sedentary behavior, including both occupation and leisure time PA. The participants in this study attended a two-week monitoring of PA between April 2012 and February 2014. Measurements may include both working and holiday periods, which cannot be separated afterward. The dim light melatonin onset (DLMO) is the gold standard objective method of detecting circadian phase in humans.[34] Objectively measured bedtime duration and midpoint of the bedtime have been shown to give useful information of chronotype.[35] However, shortened versions of MEQ have been shown to be reliable and are widely used in epidemiological studies.[23,24,36]

Perspectives

Evening chronotype is associated with low objectively measured physical activity in both sexes and with high sedentariness among men, even after adjustments for established potential confounders and beyond strenuousness of work. Our results suggest that an individual's chronotype is worth noting when planning individualized promotion of physical activity in both public health and clinical settings. In the future, wearable technologies can offer individual measuring and support to consider individual preferences of daily sleep, wake, and high alertness timing.

Declaration of interests

All authors declare that they have no competing interests.

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Contributors

We state the following author contributions: LN, HJ, MK, RK, MN, and TJ participated in the literature search; RK, TJ, MK, and HJ designed the study; data collection was carried out by RK, TJ, MN, MK, and HJ; data analysis was completed by LN, MN, MK, HJ, RK, TJ, and LAM; data interpretation was conducted by LN, MN, MK, HJ, RK, TJ, LAM, and TJ; and LN, MN, MK, HJ, RK, TJ, LAM, and TJ wrote this manuscript. All authors read and approved the final manuscript.

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Table 1. Characteristics of the 5156 middle-aged birth cohort participants according to total physical activity tertiles.

	Men (n = 2239)				Women (n = 2917)			
	Low total PA	**Medium total PA**	**High total PA**	**p value**	**Low total PA**	**Medium total PA**	**High total PA**	**p value**
Total PA, range	**[152.3 – 956.9]**	**[957.0 – 1227.7]**	**[1227.8 – 3382.2]**		**[164.6 – 927.8]**	**[927.9 – 1170.6]**	**[1170.7 – 2733.0]**	
Total PA (MET min/day), mean (SD)	770.9 (139.3)	1089.4 (76.5)	1507.3 (279.4)		758.5 (129.3)	1046.1 (70.2)	1399.2 (209.2)	
SED (min/day), mean (SD)	720.3 (72.6)	647.8 (63.2)	565.0 (78.4)	<0.0001	689.1 (65.7)	625.1 (61.0)	549.2(70.2)	<0.0001
Chronotype				<0.0001				<0.0001
E-type	63 (8.4)	35 (4.7)	28 (3.8)		78 (8.0)	57 (5.9)	46 (4.7)	
D-type	424 (56.8)	409 (54.8)	409 (54.8)		518 (53.2)	527 (54.2)	465 (47.8)	
M-type	259 (34.7)	303 (40.6)	309(41.4)		377 (38.7)	388 (39.9)	461 (47.4)	
Strenuousness of work, high	205 (34.3)	311 (48.4)	424 (66.6)	<0.0001	326 (40.1)	404 (48.3)	535 (63.8)	<0.0001
Current smoking	185 (40.0)	159 (34.3)	119 (25.7)	<0.0001	182 (37.5)	175 (35.9)	131 (26.8)	0.003
Heavy alcohol users*	83 (11.1)	69 (9.2)	52 (7.0)	0.021	66 (6.8)	75 (7.7)	77 (7.9)	0.599
High education	214 (29.5)	180 (24.6)	145 (19.8)	<0.0001	352 (37.8)	302 (32.4)	244 (24.7)	<0.0001
Married/cohabiting	565 (75.9)	627 (84.0)	616 (83.2)	<0.0001	731 (75.3)	759 (78.3)	775 (80.0)	0.041
No current diagnosed diseases	185 (24.8)	206 (27.6)	208 (27.9)	0.328	266 (27.3)	320 (32.9)	354 (36.5)	<0.0001
BMI, mean (SD)	28.1 (4.8)	27.2 (4.0)	26.5 (3.8)	<0.0001	27.9 (5.9)	26.0 (4.9)	25.2 (4.2)	<0.0001
WC (cm), mean (SD)	99.8 (12.6)	96.9 (11.0)	95.2 (11.1)	<0.0001	90.2 (14.3)	86.1 (12.2)	84.2 (11.1)	<0.0001

Abbreviations: PA – physical activity; SED – time spent on sedentary behaviors, intensity < 2 MET; M-type – morning chronotype, D-type – day chronotype, E-type – evening chronotype; BMI – body mass index; WC – waist circumference. Tertiles low, medium, and high were defined by two cut points that divided the participants into three groups of equal size based on the distribution of physical activity among the controls. Values are numbers (%) unless otherwise stated. Numbers do not match due to missing values.

*Heavy alcohol users: men ≥ 40 g/day; women ≥ 20 g/day.

Table 2. Characteristics of the 5156 middle-aged birth cohort participants according to chronotypes.

	Men (n = 2239)				Women (n = 2917)			
	M-type	D-type	E-type	p value	M-type	D-type	E-type	p value
Total PA (MET min/day), mean (SD)	1145.4 (348.2)	1119.4 (356.9)	995.4 (339.7)	<0.0001	1096.8 (305.2)	1053.0 (289.5)	995.1 (341.0)	<0.0001
SED (min/day), mean (SD)	639.3 (90.8)	643.7 (96.5)	685.5 (110.6)	<0.0001	617.2 (86.8)	622.6 (85.8)	635.5 (98.7)	0.020
Strenuousness of work, high	398 (54.6)	496 (47.5)	46 (45.1)	0.007	547 (52.1)	639 (49.7)	79 (52.3)	0.490
Current smoking	186 (21.4)	249 (20.0)	28 (22.2)	0.664	190 (15.5)	244 (16.2)	54 (29.8)	<0.0001
Heavy alcohol users*	81 (9.3)	105 (8.5)	18 (14.3)	0.092	77 (6.3)	119 (7.9)	22 (12.2)	0.013
High education	171 (20.9)	337 (27.9)	31 (25.2)	<0.0001	359 (30.2)	484 (33.3)	55 (31.8)	0.232
Married/cohabiting	713 (82.2)	1004 (81.0)	191 (72.8)	0.042	971 (79.5)	1196 (77.6)	125 (69.1)	0.006
No current diagnosed diseases	254 (29.2)	324 (26.1)	21 (16.7)	0.009	456 (37.2)	448 (29.7)	36 (19.9)	<0.0001
BMI, mean (SD)	27.5 (4.2)	27.0 (4.1)	28.4 (5.1)	<0.0001	26.3 (5.2)	26.3 (5.0)	27.8 (6.1)	0.001
WC (cm), mean (SD)	97.8 (11.8)	96.6 (11.4)	100.5 (13.2)	<0.0001	86.4 (12.8)	86.7 (12.5)	90.6 (14.7)	<0.0001

Abbreviations: M-type – morning chronotype, D-type – day chronotype, E-type – evening chronotype; PA – physical activity; SED – time spent on sedentary behaviors, intensity < 2 MET; BMI – body mass index; WC – waist circumference. Values are numbers (%) unless otherwise stated. Numbers do not match due to missing values.

Table 3. Variables significantly associated with the total time spent on objectively measured physical activity (MET min/d) at midlife in a population-based birth cohort according to general linear model analyses.

	Men (n = 2239)		Women (n = 2917)	
	Model R^2 = 12.4, **p < 0.0001***		Model R^2 = 12.7, **p < 0.0001***	
Variable	Adjusted B (95 % CI)	p-value	Adjusted B (95 % CI)	p-value
Chronotype		**0.014**		**0.002**
E-type (referent)	0		0	
D-type	75.2 (8.1 to 142.4)	**0.028**	20.9 (–25.7 to 67.5)	0.380
M-type	98.6 (30.2 to 167.1)	**0.005**	57.8 (10.5 to 105.0)	**0.017**
Strenuousness of work, high vs. light (referent)	193.4 (163.8 to 223.0)	**< 0.0001**	151.2 (129.3 to 173.2)	**< 0.0001**
Non or former smokers vs. current smokers (referent)	57.0 (19.1 to 95.0)	**0.003**	34.4 (4.3 to 64.5)	**0.025**
Constant	1176.8 (1036.5 to 1317.0)	**< 0.0001**	1315.9 (1226.1 to 1405.7)	**< 0.0001**

Abbreviations: PA – physical activity; M-type – morning chronotype, D-type – day chronotype, E-type – evening chronotype. Significant results ($p < 0.05$) are indicated in bold.

*Adjusted for heavy alcohol consumption (men ≥ 40 g/day; women ≥ 20 g/day), marital status (living with a partner/living alone), prevalence of diagnoses (cardiovascular disease, diabetes mellitus, cancer, musculoskeletal diseases, mental disorder, and thyroid disease; no/one or more), body mass index (BMI), and seasonal PA collection time (summer/winter).

Table 4. Variables significantly associated with the total time spent on objectively measured sedentary time (min/d) at midlife in a population-based birth cohort according to general linear model analyses.

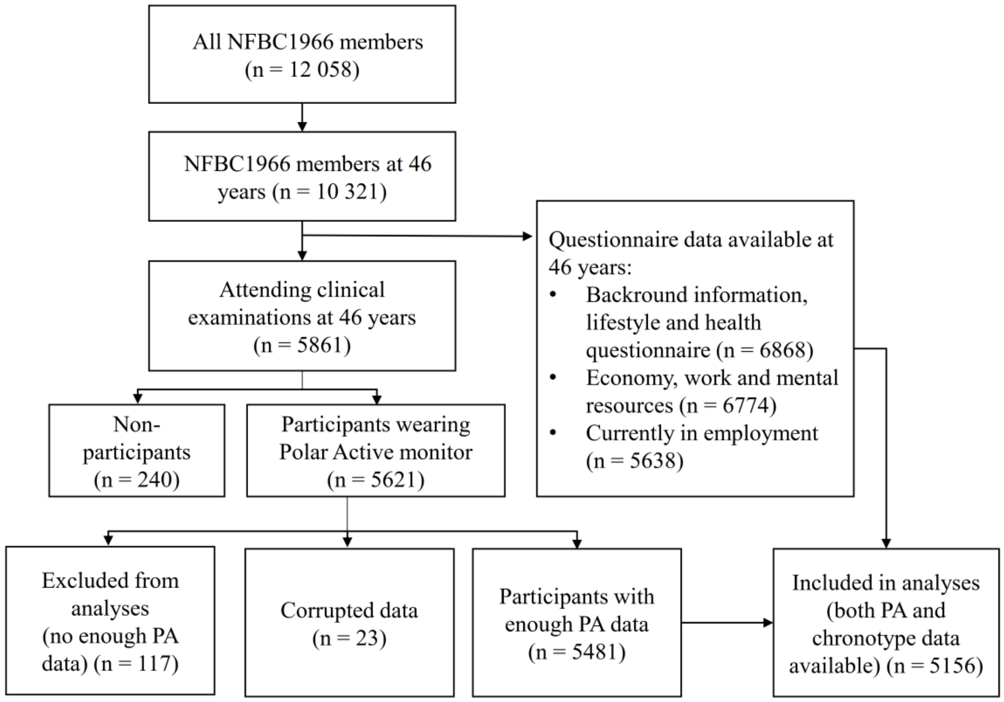
	Men (n = 2239)		Women (n = 2917)	
	Model R^2 = 14.6, **p < 0.0001***		Model R^2 = 18.2, **p < 0.0001***	
Variable	Adjusted B (95 % CI)	p-value	Adjusted B (95 % CI)	p-value
Chronotype		**< 0.0001**		0.257
E-type (referent)	0		0	
D-type	–35.8 (–53.8 to –17.8)	**< 0.0001**	–5.5 (–15.4 to 11.2)	0.412
M-type	–38.6 (–56.9 to –20.2)	**< 0.0001**	–9.4 (–22.7 to 3.8)	0.163
Strenuousness of work, high vs. light (referent)	–60.9 (–68.9 to –52.9)	**< 0.0001**	–61.9 (–68.1 to –55.8)	**< 0.0001**
Non or former smokers vs. current smokers (referent)	–2.0 (–12.1 to 8.2)	0.8	–4.3 (–12.8 to 4.1)	0.315
Constant	645.4 (607.8 to 683.0)	**< 0.0001**	568.8 (543.6 to 594.0)	**< 0.0001**

Abbreviations: SED – sedentary time; M-type – morning chronotype, D-type – day chronotype, E-type – evening chronotype. Significant results ($p < 0.05$) are indicated in bold.

*Adjusted for heavy alcohol consumption (men ≥ 40 g/day; women ≥ 20 g/day), marital status (living with a partner/living alone), prevalence of diagnoses (cardiovascular disease, diabetes mellitus, cancer, musculoskeletal diseases, mental disorder and thyroid disease; no/one or more), body mass index (BMI), and seasonal PA collection time (summer/winter).

Figure Legends:

Figure 1. Northern Finland Birth Cohort (1966) participants



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