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Tracking and Changes in Daily Step Counts among Finnish Adults

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ABSTRACT

YANG, X., J. KULMALA, H. HAKONEN, M. HIRVENSALO, S. P. ROVIO, K. PAHKALA, T. KUKKO, N. HUTRI-KÄHÖNEN, O. T. RAITAKARI, and T. H. TAMMELIN. Tracking and Changes in Daily Step Counts among Finnish Adults. *Med. Sci. Sports Exerc.*, Vol. 53, No. 8, pp. 1615–1623, 2021. **Purpose:** This study aimed to investigate the tracking and changes of steps per day in adults and their determinants over 13 yr. **Methods:** A total of 2195 subjects (1236 women) 30–45 yr of age were randomly recruited from the ongoing Cardiovascular Risk in Young Finns Study in 2007 and were followed up in 2020. Steps per day, including both total and aerobic steps per day, were monitored for seven consecutive days with a pedometer in 2007–2008 and 2011–2012 and with an accelerometer in 2018–2020. Tracking was analyzed using Spearman's correlation. Stability and changes of steps per day over time in both low-active and high-active groups (based on median values) were described by percentage agreements, kappa statistics, and logistic regression. Associations of sex, age, and body mass index with the initial number and changes in steps per day were analyzed using linear growth curve modeling. **Results:** Tracking correlations of total steps per day at 4-, 9-, and 13-yr intervals were 0.45–0.66, 0.33–0.70, and 0.29–0.60, while corresponding correlations for aerobic steps per day were 0.28–0.55, 0.23–0.52, and 0.08–0.55, respectively. Percentage agreements were higher than 54%, and kappa statistics ranged from slight to fair over time. Compared with the low-active group, the high-active group at baseline had a higher probability of being active later in adulthood. Female sex and higher age were associated directly with the initial number of steps per day and inversely with changes in the number of steps per day. Body mass index was inversely associated with the initial number of steps per day and changes in the number of total steps per day. **Conclusion:** The 13-yr tracking of steps per day in adulthood was found to be low to moderately high. Daily ambulatory activity is essential to maintaining an active lifestyle throughout adulthood. Changes in the amount of adult steps per day vary by sex, age, and BMI. **Key Words:** AMBULATORY ACTIVITY, ADULTHOOD, STABILITY, MULTILEVEL ANALYSIS, AGE COHORTS, DEVICES

Regular physical activity (PA) is well documented as an important lifestyle factor for physical and mental health (1). PA, defined as any bodily movement produced by skeletal muscles that leads to increased energy expenditure above resting metabolic equivalents (2), has multifaceted favorable effects on health (3,4) and contributes to a long-term beneficial effect on indicators of chronic noncommunicable diseases (5,6). Increased PA, particularly as measured by steps per day, has been linked to reduced risk for all-cause mortality in adults (7).

Over the past decade, there has been increased interest in the tracking of PA from childhood to adolescence and beyond into adulthood. By definition, tracking leads to a tendency for individuals to maintain their rank or position within a group over time (8,9) and facilitates predicting subsequent observations

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from earlier estimates (10). Findings from several systematic reviews (8,9,11,12) reflect low to moderate PA tracking correlations from childhood through adolescence to adulthood and during adulthood. These results probably reflect an existing within-person variability in PA over the life span (13). It is notable that the stability of PA is lower in women than in men and remains at the same order of magnitude over a short interval during adulthood (9,14,15). However, the vast majority of studies have relied upon self-reporting questionnaires, which may not be the most reliable method for measuring PA.

To improve the precision and accuracy of PA measurements in intervention and epidemiological studies, motion sensors (e.g., pedometers and accelerometers) are used to quantify PA. Despite the increase in device-derived PA tracking research generally, only a few studies have focused on the long-term stability of adults' device-derived PA, and the follow-up time was short (16,17). Two studies using pedometers reported a moderate to moderately high tracking of overall mean steps per day on either two or three phases over 4–6 months among older adults (mean age, 60 yr) (17) and 1 yr in middle-age adults (mean age, 42 yr) (16). Another longitudinal study reported tracking of pedometer-determined PA from early adolescence to adulthood in five phases over 16 yr (18). In that study, a mostly moderate tracking of daily steps was observed during young adulthood (ages 22 to 28 yr). All three studies suggest a large variation in device-derived PA levels across sex, age, and body mass index (BMI). Importantly, no previous study has reported tracking of daily aerobic steps (i.e., those taken at a cadence of greater than 60 steps per minute for 10 or more consecutive minutes) that was linked to certain health benefits (19,20). The tracking and changes in daily aerobic steps may also have been biased (e.g., depending on sex, age, and BMI).

The present longitudinal study is a part of the ongoing Cardiovascular Risk in Young Finns Study (YFS) (21) that included pedometry as an integral part of the overall PA measures in 2007–2008 (22) and 2011–2012 (23). The latest device-derived PA measurement was completed using accelerometry from June 2018 to June 2020. Accelerometry is applied instead of pedometry because it has been advocated as a measure of the frequency and intensity of PA and a more accurate evaluation of walking cadence than a pedometer if it is attached to the waistband (24). Although differences between pedometry and accelerometry may exist in the patterns of PA used to capture step data (25), mixed-use devices will be applied to track steps per day over time in this longitudinal study because of their close interrelationship (22,26,27). In this study, steps per day was determined in two domains—daily total and aerobic steps—that reflect the nature of ambulatory activity. However, no previous study has been conducted to describe the tracking of patterns and levels of steps per day during adulthood in both sexes and within many age cohorts. Accordingly, the purpose of this study was to evaluate the longitudinal tracking and changes of steps per day for women and men in six age cohorts of adults over a 13-yr follow-up period, taking into account the baseline characteristics of participants in the YFS.

MATERIALS AND METHODS

Participants. The YFS data were initially collected in 1980 from six age cohorts of children and adolescents born in 1962, 1965, 1968, 1971, 1974, and 1977 when they were 3, 6, 9, 12, 15, and 18 yr old, respectively. Of the 4326 boys and girls, 3596 (83%) participated at baseline and were followed up in 1983, 1986, 1989, 1992, 2001, 2007, 2011 (21,28), and 2018–2020. Participants were randomly selected from five university cities (Helsinki, Kuopio, Oulu, Tampere, and Turku) with medical schools and their surrounding rural communities. For this study, we used the year 2007 as the baseline because that was the year the pedometer was introduced in the study protocol to measure steps per day. This study included 2195 participants (56% women) 30–45 yr of age (mean age, 37.6 yr) at the 13-yr follow-up. Of these, 709 participants (32.3%) had three measurements, 754 (34.4%) had two measurements, and 732 (33.3%) had one measurement. We acknowledge that by following the participants over time using a longitudinal design, the initial device-derived PA is not fully determined for the baseline cohort because not all participants started in 2007. Ethics approval was obtained from the ethics committees of each of the five participating universities, and written informed consent was obtained from all participants in accordance with the Helsinki Declaration (21).

Daily steps. Steps per day was measured by motion sensors using Omron Walking Style One pedometer (HJ-152R-E; Omron, Kyoto, Japan) in 2007–2008 and 2011–2012 and triaxial ActiGraph accelerometer (GT3X+ and wGT3X+; ActiGraph Pensacola, FL) in 2018–2020. Pedometers were attached to the waistband or belt, placed on the right hip for seven consecutive days, and the time and step count per day was recorded in the activity log. Participants were asked to report their typical activities (i.e., PA) and to take the pedometer off for bathing or water activities. They were also given pedometer logs with instructions to log their pedometer use daily, as applied by the study researchers. On the eighth day, participants were instructed to send their pedometer logs and the pedometer to the study center using a padded mailbag in a self-addressed, stamped envelope that was provided to all participants. Data were considered valid if the participant reported wearing the pedometer for all waking hours per day on at least 4 d of seven consecutive days (22). Accelerometers were attached to an elastic waistband and placed on the right hip for seven consecutive days and nights. In contrast to the pedometers, participants using the accelerometers were instructed to wear them when sleeping, but, like the pedometers, the accelerometers were taken off for bathing and water activities. Participants kept a diary in which they entered their sleeping and working periods, an estimation of sleeping time, and whether anything extraordinary, such as illness, occurred during the measurement period. Data were collected at a 60-Hz sample rate using normal filter and later averaged to 60-s epochs. Participants with four or more days of valid data were included in the analysis. A valid day for the accelerometers was defined as at least

600 min of wearing time, and nonwearing time was defined as 60 min of consecutive zero count per minute (29).

Accelerometers provided sufficient data on steps per day but also richer and more detailed data on total PA intensity, time spent sedentary, and sleep duration (30,31). Only the steps per day data were used for this study. The instruments and protocol for data collection have been shown to provide valid and reliable step-counting information, and high correlations ($r \geq 0.90$) have been observed between the step counts from both devices (22,26,27). It is worth noting that the method of transforming movement into daily steps differs between Omron and ActiGraph (25); therefore, the selection of steps per day cutoff points and the data reduction method may have a pronounced effect on the comparison of absolute values from the two devices. To reduce the undesirable effects of numerical interpretations, the statistical analysis in this study was designed such that the use of an absolute value of steps per day was avoided, and there was emphasis on correlative analyses.

The Omron pedometers tracked steps per day and distinguished aerobic steps from total daily steps. Aerobic steps were accumulated in bouts of at least 10 min when at least 60 steps per minute were counted. The ActiGraph aerobic steps were calculated in a similar manner. Continuous steps per day measurement as well as categorized steps per day levels were used in the descriptive and correlation analyses. Using the median value of steps per day, participants were divided into two groups: a high-active group (daily steps at and above median values) and a low-active group (daily steps below median values).

Baseline covariates. In 2007, the participants' weight (kg) and height (cm) were measured, and BMI ($kg \cdot m^{-2}$) was calculated. Residential status was dichotomized into urban and rural areas. Parental educational attainment was self-reported and measured as total number of school years, and their occupation was divided into two categories according to criteria of the Central Statistical Office of Finland: manual and nonmanual work. Number of children was queried, and two categories were established as no child and at least one child. Smoking habits were ascertained by a questionnaire, and those participants reporting daily smoking were deemed as smokers. Alcohol consumption frequency was queried and dichotomized into less than once a week and at least once a week.

Statistical analysis. Descriptive statistics (mean, SD, and median) were collected to describe sample characteristics and steps per day at each time point (2007–2008, 2011–2012, and 2018–2020) separately for women and men in six age cohorts. Gender comparisons of steps per day at each measurement were evaluated using Student's *t*-test. The tracking of steps per day for the time intervals was assessed by Spearman rank-order correlation coefficients separately for women and men in the total study population as well as separately for different age cohorts, and for low- and high-active groups. The strength of the Spearman correlation was interpreted as low (<0.30), moderate (0.30–0.60), and moderately high (>0.60) (8). Percent agreement and weighted kappa coefficient were used to estimate the agreement, stability, and change between low- and high-active groups across the years. Kappa values were interpreted as follows: ≤0 poor, 0.01–0.20 slight, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 substantial, and >0.80 almost perfect (32). Logistic regression analysis was used to estimate odds ratios (OR) and 95% confidence intervals (CI) for the high-active group compared with the low-active group using the low-active group as the reference group and adjusting for baseline age, residential place, education, occupation, having children, BMI, current smoking, and regular alcohol use. Linear growth curve modeling was extended to a structural equation modeling framework for analyzing the repeated measures. The model with latent variables allowed for simultaneous estimation of individuals' initial levels (intercepts) and changes (slopes), and the observed variables (sex, age, and BMI) were included in the model to estimate their effects on the levels and changes of total and aerobic steps per day separately over 13 yr. The analyses were performed using SPSS Statistics version 20.0 (IBM, Armonk, NY) and Mplus statistical package version 7.0 (33). Statistical significance was set at $P < 0.05$.

Missing data were assumed to be missing at random. Full information maximum likelihood estimation with robust SE was used to estimate mean values and parameters of the models. It produced unbiased parameter estimates under the missing at random assumption and used all available information and statistical power to detect statistically significant effects.

RESULTS

Demographic and baseline characteristics of the participants are shown in Table 1. In 2007, the participants' ages ranged from 30 to 45 yr (mean = 37.7, SD = 5.1), 61% reported living in urban surroundings, and 73% had at least one child. The participants reported an average education of 15.5 yr, with 56% identified as having nonmanual employment. The participants' mean BMI was 25.8 $kg \cdot m^{-2}$, 74% were nonsmoking, and 88% reported low alcohol consumption. Women had lower BMI ($P < 0.001$), more years of education ($P < 0.001$), and

TABLE 1. Characteristics of the study sample in 2007 stratified by sex.

Variable	Both (*N* = 2195)	Women (*n* = 1236)	Men (*n* = 959)	*P**
Mean ± SD				
Age (yr)	37.7 ± 5.1	37.8 ± 5.0	37.7 ± 5.1	0.685
BMI ($kg \cdot m^{-2}$)	25.8 ± 4.6	25.2 ± 4.9	26.5 ± 4.1	<0.001
Education (yr)	15.5 ± 3.4	15.9 ± 3.3	14.9 ± 3.5	<0.001
Percentages				
Residence				
Urban	61	62	60	0.324
Rural	39	38	40	
Having children				
No child	27	24	32	<0.001
At least one child	73	76	68	
Occupation				
Manual	44	44	43	0.454
Nonmanual	56	56	57	
Current smoking				
Nonsmoker	74	80	68	<0.001
Smokers	26	20	32	
Regular alcohol use				
Less than once a week	88	95	78	<0.001
Once a week or more	12	5	22	

*The *P* value for sex difference (Student's *t*-test or χ^2 test).

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TABLE 2. Number, mean, and SD of daily step counts (total and aerobic steps per day) by sex, age, and measurement year.

	Women							Men						
	2007		2011		2020			2007		2011		2020		
Age in 2007	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD	*n*[a]	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD	*n*[a]
Total steps per day														
30	130	7781 ± 2597	109	8323 ± 2750	109	9092 ± 2925	175	97	6874 ± 2945	91	7068 ± 2403	96	8011 ± 2772	161
33	151	7846 ± 2670	138	8161 ± 2918	137	8196 ± 2520	206	83	7472 ± 2434	99	7007 ± 2493	67	8271 ± 2545	135
36	144	7551 ± 3342	148	8293 ± 3108	126	8956 ± 3279	208	103	7453 ± 2883	109	7879 ± 3312	93	9008 ± 2864	166
39	167	8147 ± 2802	165	8428 ± 3084	155	8331 ± 2725	224	110	7268 ± 2895	109	7838 ± 3278	90	8620 ± 3127	169
42	169	8312 ± 2921	167	8385 ± 3052	149	8441 ± 3009	215	115	7684 ± 3171	115	8060 ± 3177	99	9117 ± 3115	164
45	146	8279 ± 2877	165	8319 ± 3064	136	8316 ± 2910	208	105	7144 ± 2542	110	7503 ± 3225	111	8071 ± 3394	164
Total	907	8002 ± 2885	892	8323 ± 3007	812	8525 ± 2905	1236	613	7321 ± 2841	633	7587 ± 3045	556	8517 ± 3035	959
Median		7711		8011		8233			7021		7064		8189	
Aerobic steps per day														
30	130	2298 ± 2072	109	2253 ± 2198	109	1689 ± 1933	175	97	1158 ± 1587	91	1368 ± 1574	96	959 ± 1304	161
33	151	2311 ± 2026	138	2245 ± 2121	137	1507 ± 1591	206	83	1479 ± 1691	99	1127 ± 1569	67	1068 ± 1615	135
36	144	2146 ± 2470	148	2028 ± 2068	126	1895 ± 2170	208	103	1462 ± 1800	109	1436 ± 1928	93	1510 ± 1816	166
39	167	2409 ± 2003	165	2246 ± 2312	155	1378 ± 1668	224	110	1312 ± 1714	109	1370 ± 1787	90	1121 ± 1654	169
42	169	2533 ± 2000	167	2235 ± 2149	149	1603 ± 2030	215	115	1653 ± 1842	115	1738 ± 1868	99	1512 ± 1817	164
45	146	2786 ± 2118	165	2451 ± 2135	136	1591 ± 1970	208	105	1793 ± 1990	110	1606 ± 2460	111	979 ± 1469	164
Total	907	2419 ± 2119	892	2246 ± 2164	812	1599 ± 1897	1236	613	1482 ± 1786	633	1451 ± 1904	556	1193 ± 1629	959
Median		2093		1699		1007			814		775		506	

[a]Total sample size used in the model.

more often had children ($P < 0.001$) than men. Men reported more daily smoking ($P < 0.001$) and regular alcohol use ($P < 0.001$) than women. There were no significant sex differences in age, residential place, or occupational status.

The sex-specific mean steps per day for the six age cohorts at each follow-up study are shown in Table 2. The number of total and aerobic steps per day varied slightly with age for both sexes at each follow-up study. On average, the number of total daily steps was significantly higher among women than men in 2007–2008 (8002 vs 7321 steps per day, $P < 0.001$) and 2011–2012 (8323 vs 7587 steps per day, $P < 0.001$), but not in 2018–2020 (8525 vs 8517 steps per day, $P = 0.963$). The number of average daily aerobic steps was significantly greater among women than men in all follow-up studies: 2007–2008 (2419 vs 1482 steps per day, $P < 0.001$), 2011–2012 (2246 vs 1451 steps per day, $P < 0.001$), and 2018–2020 (1599 vs 1193 steps per day, $P < 0.001$). Median total values of steps per day were 7711, 8011, and 8323 for women and 7021, 7064, and 8189 for men in the three follow-up studies, whereas the corresponding median values of aerobic steps per day were 2093, 1699, and 1007 for women and 814, 775, and 506 for men, respectively.

Spearman correlation coefficients for patterns of steps per day by sex and age at the three intervals are shown in Table 3. The interage correlations for total steps per day over a 4-yr period ranged from 0.47 to 0.56 in women and from 0.45 to 0.66 in men, whereas the corresponding correlations over a 9-yr period were 0.41 to 0.70 in women and 0.33 to 0.64 in men. The correlations for total steps per day over a 13-yr period ranged from 0.34 to 0.60 in women and from 0.29 to 0.59 in men. All correlations were statistically significant. For aerobic steps per day, the interage correlations over the 4-yr period were all highly significant in all age-groups and ranged from 0.30 to 0.55 in women and from 0.28 to 0.53 in men, whereas the corresponding correlations over the 9-yr period were 0.23 to 0.49 and 0.26 to 0.52, respectively. All correlations were highly

TABLE 3. Spearman's correlation coefficient of daily step counts by sex, age, and group at different time intervals.

	Women			Men		
Age in 2007	2007–2011	2011–2020	2007–2020	2007–2011	2011–2020	2007–2020
Total steps per day						
30	0.47**	0.52**	0.48**	0.45**	0.51**	0.43**
33	0.56**	0.48**	0.46**	0.47**	0.52**	0.49**
36	0.53**	0.70**	0.60**	0.63**	0.50**	0.29*
39	0.50**	0.53**	0.48**	0.66**	0.33*	0.35**
42	0.49**	0.41**	0.40**	0.63**	0.47**	0.58**
45	0.47**	0.53**	0.34**	0.56**	0.64**	0.40**
High activity	0.39**	0.41**	0.32**	0.45**	0.41**	0.27**
Low activity	0.37**	0.43**	0.32**	0.30**	0.55**	0.26**
Aerobic steps per day						
30	0.30**	0.23	0.37**	0.28*	0.34**	0.34*
33	0.42**	0.44**	0.25*	0.30*	0.42**	0.27
36	0.55**	0.49**	0.38**	0.45**	0.52**	0.41**
39	0.36**	0.35**	0.33**	0.48**	0.26*	0.08
42	0.37**	0.43**	0.27**	0.53**	0.44**	0.55**
45	0.40**	0.43**	0.29**	0.38**	0.50**	0.48**
High activity	0.43**	0.38**	0.31**	0.48**	0.38**	0.39**
Low activity	0.26**	0.36**	0.16**	0.24**	0.38**	0.26**

*$P < 0.05$ (two-tailed).
**$P < 0.01$ (two-tailed).

TABLE 4. Stability of daily step counts by sex at different time intervals.

	Women			Men		
Follow-up Year	Kappa (95% CI)	Percent Agreement	Spearman Correlation	Kappa (95% CI)	Percent Agreement	Spearman Correlation
2007–2011						
Total steps per day	0.30 (0.23–0.38)**	65.2	0.51**	0.38 (0.29–0.47)**	69.2	0.58**
Aerobic steps per day	0.31 (0.24–0.38)**	65.5	0.42**	0.31 (0.21–0.40)**	65.4	0.42**
2011–2020						
Total steps per day	0.39 (0.32–0.46)**	70.1	0.53**	0.35 (0.26–0.44)**	68.0	0.50**
Aerobic steps per day	0.27 (0.20–0.35)**	64.7	0.40**	0.31 (0.22–0.41)**	65.6	0.41**
2007–2020						
Total steps per day	0.29 (0.22–0.37)**	65.0	0.45**	0.26 (0.16–0.36)**	63.5	0.43**
Aerobic steps per day	0.09 (0.01–0.16)*	54.1	0.31**	0.27 (0.17–0.37)**	62.9	0.38**

*$P < 0.05$ (two-tailed).
**$P < 0.01$ (two-tailed).

significant except in the group of 30-yr-old women. The correlations over the 13-yr period ranged from 0.25 to 0.38 in women and from 0.08 to 0.55 in men and were significant, except in the groups of 33- and 39-yr-old men.

Table 3 also shows the Spearman correlation coefficients of daily steps in different time intervals separately for the high- and low-active groups. For total steps per day, the correlation coefficients were all significant in the two activity groups in both sexes at 4-, 9-, and 13-yr intervals, ranging from 0.32 to 0.41 in women and from 0.27 to 0.45 in men in the high-active group and from 0.32 to 0.43 in women and from 0.26 to 0.55 in men in the low-active group. For aerobic steps per day, the highest correlations were observed in the high-active group at 4-yr intervals, with a correlation of 0.43 for women and 0.48 for men, and in the low-active group at 9-yr intervals, with a correlation of 0.36 for women and 0.38 for men. In both sexes, the tracking correlations of the high-active group were higher than that of the low-active group in almost all intervals.

Table 4 presents kappa coefficients, percent agreement, and average Spearman's correlation for steps per day at different time intervals. Kappa coefficients for total steps per day ranged from 0.29 to 0.39 in women and 0.26 to 0.38 in men and for aerobic steps per day ranged from 0.09 to 0.31 in women and 0.27 to 0.31 in men at the three time intervals. The overall percent agreement was higher than 60% at all intervals, with the exception of the correlation for women in aerobic steps per day at the 13-yr interval. The correlations of total steps per day were 0.51, 0.53, and 0.45 in women, and 0.58, 0.50, and 0.43 in men between the 4-, 9-, and 13-yr follow-up intervals, respectively. The correlations of aerobic steps per day were 0.42, 0.40, and 0.31 in women, and 0.42, 0.41, and 0.38 in men between the follow-up intervals, respectively.

Compared with the low-active adults at baseline, the high-active adults had a higher probability of being active over 13 yr (Table 5). After adjusting for baseline age, residential place, education, occupation, having children, BMI, current smoking, and regular alcohol use, the associations remained significant for total steps per day (women, OR = 5.0, 95% CI = 3.3–7.5; men, OR = 4.2, 95% CI = 2.4–7.3) and for aerobic steps per day (women, OR = 4.5, 95% CI = 3.0–7.0; men, OR = 3.8, 95% CI = 2.2–6.6).

Figure 1 illustrates the results of unstandardized regression coefficients for sex, age, and BMI on initial number and change in total steps per day (Fig. 1A) and aerobic steps per day (Fig. 1B) over 13 yr. Female sex was related directly to the initial number and inversely to the change of total steps per day (Fig. 1A). This indicates that the baseline total steps per day was more favorable in women than in men, whereas changes in total steps per day were less favorable in women. Higher age was associated directly with the initial number and inversely with the change of total steps per day. BMI was inversely associated with both the initial number and the change of total steps per day. This indicates that adults with higher BMI had lower baseline numbers of total steps per day and were less likely to change the number of total steps per day over time than their counterparts with lower BMI. The results for aerobic steps per day (Fig. 1B) were similar to the results for total steps per day. Baseline numbers and changes in aerobic steps per day in women and in older participants were consistent with those observed in total steps per day. BMI was inversely associated with the baseline number of aerobic steps per day but not with changes in aerobic steps per day.

DISCUSSION

The current study examined the 13-yr tracking of steps per day (i.e., total and aerobic steps per day) during adulthood in six age cohorts of women and men. As expected, tracking coefficients tended to be lower for the longer time intervals in both sexes for either the mean steps per day or the two activity groups. Most importantly, being physically active at baseline had higher odds of being active at 13-yr follow-up than being

TABLE 5. Odds of being physically active at 13-yr follow-up according to activity levels at baseline by sex.

	Women			Men		
		Model 1[a]	Model 2[b]		Model 1[a]	Model 2[b]
Baseline Level	*n*	OR (95% CI)	OR (95% CI)	*n*	OR (95% CI)	OR (95% CI)
Total steps per day						
Low activity	247	1.0	1.0	102	1.0	1.0
High activity	341	5.0 (3.4–7.1)	5.0 (3.3–7.5)	216	3.8 (2.3–6.4)	4.2 (2.4–7.3)
Aerobic steps per day						
Low activity	404	1.0	1.0	214	1.0	1.0
High activity	184	4.8 (3.2–6.9)	4.5 (3.0–7.0)	104	2.7 (1.7–4.4)	3.8 (2.2–6.6)

[a]Model 1 adjusted for baseline age.
[b]Model 2 additionally adjusted for residential place, education, occupation, having children, BMI, current smoking, and regular alcohol use at baseline.

EPIDEMIOLOGY

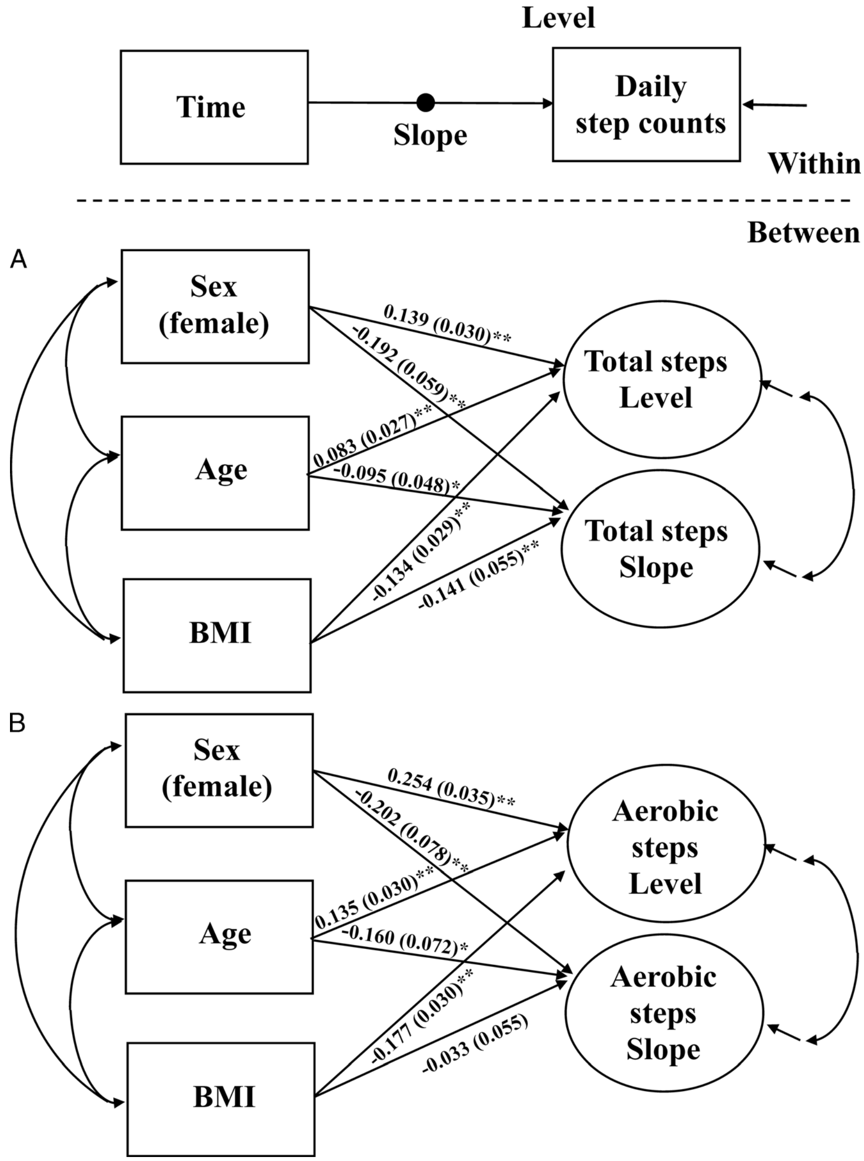

FIGURE 1—Growth model for total steps per day (A) and aerobic steps per day (B). Levels and slopes of both variables were predicted by sex, age, and BMI. Unstandardized regression coefficients (SE) are presented. *P < 0.05, **P < 0.01.

physically low active. Female sex and higher age were associated directly with baseline numbers and inversely with change in steps per day, whereas BMI was inversely associated with baseline amount of steps per day and change in total steps per day. These findings suggest that daily ambulatory activity, combined with reducing BMI in a younger age, increases the probability of being active in midlife.

In the few previous tracking studies of pedometer-determined ambulatory activity in adulthood, the results have shown positive tracking correlations (16–18). The first tracking study of mean steps per day by Tudor-Locke et al. (16) for the general adult population was reported using both Pearson's and Spearman's correlations. They found a moderate to high temporal tracking over a 1-yr follow-up in women (0.52–0.65) and men (0.53–0.63) between 30 and 59 yr of age. Newton et al. (17) further reported that the ranking order of mean steps per day in adults (mean age, 60 yr) remained stable in either two (0.57) or three (0.76) phases over 4–6 months, although it was analyzed using an intraclass correlation coefficient. Using the longitudinal pedometer-determined PA data from early adolescence to adulthood, Raustorp and Fröberg (18) have shown that the tracking of mean steps per day by the Pearson's correlations in the last 6 yr (2010–2016) is 0.39 for women and 0.50 for men 22 to 28 yr of age. In the present study, the Spearman's correlations of mean total and aerobic steps per day were higher in a shorter period during adulthood and lower with the longer follow-up. Specifically, the tracking coefficients for mean steps per day were significant at the 4-yr interval and were moderately high in six age cohorts for both sexes, ranging from 0.47 to 0.56 in women and from 0.45 to 0.66 in men, with corresponding explained variances of 22%–31% and 20%–44%, respectively. These longitudinal results are consistent with previous findings on the tracking of self-reported PA (8,9,28), suggesting that tracking coefficients of regular PA were generally low to moderately high in both subjective and objective measures of PA and tended to decrease as the time interval increased. However, self-reporting and device-derived measuring of PA may differ according to type, intensity, and duration in adult daily PA (34).

No previous studies reported the stability coefficients for mean aerobic steps per day in adults. In this study, the correlations for the 4-yr interval were significant in all age cohorts, ranging from 0.30 to 0.55 in women and from 0.28 to 0.53 in men. Corresponding correlations for the 9-yr interval were 0.23–0.49 in women and 0.26–0.52 in men. However, the tracking coefficients for the 13-yr interval were low to moderate for both sexes in all age cohorts. In general, the tracking correlation of aerobic steps per day was lower than that of total steps per day in both sexes. This difference may be influenced by the fact that the amount of aerobic steps per day during adulthood tends to decrease over time.

Tracking coefficients of device-derived PA are usually calculated using Pearson's, Spearman's, or both correlations, showing the extent to which individuals maintain the same PA level ranking or position within a group over time. The tracking of total steps per day in adults has been reported before, but previous research has not evaluated whether the tracking of steps per day can be distinguished between high- and low-active groups. We found that the stability of total steps per day was similar for both groups, and a higher stability of aerobic steps per day was observed for the high-active group than for the low-active group. This may indicate the importance of public health strategies aimed at increasing the amounts of daily activity in low-active adults and developing ambulatory activity to maintain throughout life. Additional research is needed to examine the societal and individual determinants of walking cadences in adults to better understand how to promote overall levels of PA over the course of adult life.

Although a moderate degree of steps per day tracking at the 4-, 9-, and 13-yr intervals was observed, the kappa coefficients are no better than fair, according to Landis and Koch (32). The low reliability for steps per day may be due to the fact that a subjective rating was done. This could lead to different judgments of steps per day when participants are tested in two distinct categories. Furthermore, results from the analyses of agreement for the pattern of steps per day were inconsistent. Over one-third of high-active adults showed stability in total steps per day over time, whereas a similar proportion of low-active adults showed stability in aerobic steps per day across time. These results indicated that the possible maintenance of two stable ambulatory activities in adults may result in the restriction of these ranges in activity behaviors. Thus, this raises awareness and understanding of the complex nature of steps per day in the context of PA intervention.

Notably, higher steps per day levels at baseline also increased the probability of being active later in adulthood. This finding is consistent with our previous study indicating that increased and sustained active commuting in youth predict overall PA in adulthood (35). The study adds to previous literature by showing similar results when objective measures of PA are applied during the transition from youth to middle age. Furthermore, the mean total steps per day at baseline were 7700 steps for women and 7000 steps for men, which were somewhat lower than those observed in previous studies whose results indicated a mean for daily steps of 8600–9800 for women (16,18) and 7600–9600 steps for men (16–18). Differences in the median steps of active participants may contribute to the different findings in our study as compared with previous research (16) and also reflect variations in the data collection procedures, individual responses to the YFS survey, and number of separate age ranges.

In this study, sex, age, and BMI differences in initial numbers and changes of steps per day were apparent in early and middle adulthood. Women who initially had a greater number of steps per day had less favorable changes in steps per day than men. Previous studies have reported both similar (18) and contrasting results (16,17). There are several explanations for these mixed results. First, there may be cultural differences operating. In Finland, over 70% of women have worked outside the home (22). We also found a sex difference in self-reported levels of walking and biking to work, suggesting that women were more likely to actively commute than men during adulthood (35). In the same vein, the level of education in women was higher than that of men in our Finnish study population, which is not the case in most other countries. It is expected that educated women who are more health conscious will be stronger tracking with increasing frequency of daily PA. It is also possible that the devices were unable to capture certain PA (e.g., cycling), which might result in an underestimation of the development of steps per day levels over the follow-up time, particularly for women. Furthermore, older participants who initially had higher numbers of steps per day had less favorable changes in steps per day compared with younger participants. These results are inconsistent with previous research, indicating that there is no significant difference in mean steps per day between two/three valid assessments for the two age-groups (17). Tudor-Locke et al. (16) highlighted clearly age-related patterns in the stability of mean steps per day for two measurements in women, but not in men. However, our sample differed from those studies in that it only included adults in six age cohorts and potentially targeted young adults that will make the greater contribution to the sustainable development of PA levels over the long term. In addition, adults with a higher BMI were associated with a lower number of steps per day at baseline and had a lower number of total steps per day at follow-up than those with a lower BMI. Our finding is consistent with previous research pointing to the importance of BMI in the association between baseline and temporal changes in mean steps per day across a range of ages and periods (16–18).

The strengths of this study include its prospective study design with three objective, device-derived measures of PA over a 13-yr period, a representative population-based sample covering ages 30 to 58 yr in six age cohorts, and major potential determinants. This allowed us to use a linear growth curve modeling approach to analyze the intercepts and slopes of total and aerobic steps per day from early to late–middle adulthood that afforded the possibility of identifying the role of age, sex, and BMI for changes in total and aerobic steps per day, resulting in substantial reductions in misclassification bias. Multilevel models were used to maximize the usefulness of data by including not only total steps per day but also aerobic steps per day for all study participants. A limitation of our study was the use of pedometers in the first two phases and accelerometers in the final phase to assess steps per day, as results could be affected by a device bias caused by different objective measures. Pedometers tend to underestimate step frequency compared with accelerometers; in addition, they were not worn for at least half an hour before bedtime nor upon waking in the morning. By contrast, accelerometers were worn when sleeping or awake, so there should not be a real nonwearing time gap. However, such activities comprise only a small amount of low-intensity walking activity, and the mean difference between the two devices for American adults is approximately 500 steps per day (25). Although this fact does not hamper the current analyses of tracking, stability, and determinants of change, it is important to note that it is not suitable to directly compare the absolute step values at different points in time (25). To diminish the undesirable effects on the interpretations, the statistical analyses are designed to avoid using absolute values of daily steps, and the emphasis of objective measures for tracking steps per day over time is on the correlative analysis. Finally, devices measuring steps are best suited to walking, jogging, and similar kind of ambulatory activities, but they do not capture the full range of PA (e.g., weight training, swimming, and cycling) and thus may underestimate overall PA.

CONCLUSIONS

To our knowledge, this is the first device-derived PA tracking study following several age cohorts in adulthood over 13 yr and reporting both total and aerobic steps per day. Tracking of total and aerobic steps per day was moderate to high for the 4- to 9-yr periods but low to moderate for the 13-yr period in adults of varying ages. Higher stability in aerobic steps per day was observed in the group of high-active adults compared with low-active participants. Women and older participants had higher baseline numbers of daily steps but experienced unfavorable changes during follow-up compared with men and younger participants. Higher BMI was associated with lower numbers of daily steps at baseline and with decreasing total steps per day during the follow-up. In conclusion, sex, age, and BMI may be important determinants of the number of daily steps not only in young adulthood but also throughout adulthood. These findings suggest that daily ambulatory activity, including brisk walking, may be an important target for PA interventions aimed at increasing overall PA across the adult population.

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