Chronic diseases and objectively monitored physical activity profile among aged individuals – a cross-sectional twin cohort study

Running title: Chronic diseases and physical activity among aged

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Abstract

Introduction. High physical activity (PA) at old age indicates good functional capacity enabling independent living. We investigated how different disease conditions are associated with measured PA indicators in old women and men, and whether they recognize this association.

Materials and methods. This cross-sectional twin cohort study in Finland comprised 779 individuals (276 complete twin pairs, including 117 monozygotic pairs), who participated in hip-worn accelerometer monitoring of PA and responded to questions on diseases and mobility limitations at mean age of 73 (range 71 to 75).

Results. Of the participants, 23.2% reported having a disease restricting mobility. With sex and age in the regression model, the reported disease restricting mobility explained 11.8% of the variation in moderate-to-vigorous PA and 10.4% of the variation in daily steps. Adding stepwise other self-reported diseases and body-mass index to the model increased the explanatory power for moderate-to-vigorous PA up to 18.5% and 25.5%, and for daily steps up to 16.0% and 20.7%, respectively. In the co-twin control analysis the PA differences were smaller in disease-discordant monozygotic than dizygotic pairs.

Conclusions. Chronic disease conditions are associated with low PA, which individuals may not always recognize. Shared genetic factors may explain part of the associations.

Key words: Disease, exercise, limitation of activity, monitoring, physical activity, sedentary behaviour, twin.

Key messages

- Among community dwelling older men and women one fourth of the variation in objectively measured moderate-to-vigorous physical activity is accounted for by age, sex, body-mass index and self-reported diseases.
- Occurrence of chronic diseases is associated with low physical activity and individuals do not always recognize this.
- Healthcare professionals should pay attention to the low physical activity and mobility of individuals with chronic disease conditions before these result in limitations in independent living.

Introduction

Ageing-related overall degenerative processes or biological physiological aging as such (1), reduction of physical activity (PA) and development of specific chronic degenerative diseases (2-5) are all associated with the development of disability and mobility limitations. Exercise-based rehabilitation has been shown to be a good means in improving both the measured and self-rated function among individuals with different chronic disease (6) and exercise interventions prevent occurrence of disability among the aged (7). High participation in moderate-to-vigorous physical activity (MVPA) at older age is an indicator of good physical fitness and health, and consequently predicts low risk of disability and death among older individuals (8,9).

While overlapping among older people, PA level as such is not a direct indicator of mobility limitations, but high PA level quite directly indicates that the individual does not have significant physical mobility limitations. The prevalence of mobility limitations depends on the definition used (10). Difficulties related to walking or climbing stairs (11-13) as well as walking outdoors (14) are common indicators used to quantify physical mobility capabilities.

In addition to low PA level, sedentary behaviour (SB) has been suggested to be detrimental to health in particular among those with low MVPA (Biswas et al. 2015, Ekelund et al. 2016, Patterson et al. 2018). Occurrence and progression of chronic diseases may lead to more sedentary lifestyle.

Inter-individual genetic differences in the liability to develop obesity and many chronic diseases are substantial (15,16). Likewise, genetic factors affect fitness and participation in

PA (17,18). However, in addition to genetic factors, there may also be factors related to childhood environment that predispose people to different clusters of these factors (8). Genetic pleiotropy (8,16) means that shared genetic factors may underlie both PA and disease risk providing an alternative explanation than a causal one to the observed association between PA and later disease.

By studying outcomes in twin pairs discordant for exposure to different health habits and health outcomes, the possible confounding contributions of genetic and shared early childhood experiences can be taken into account. Twin pairs nearly always share the same childhood family environment. Dizygotic (DZ) pairs share, on average, half of their segregating genes (like siblings), while monozygotic (MZ) pairs are genetically identical at the sequence level. The co-twin control analyses among discordant monozygotic twin pairs, in particular, allow stronger estimates on causal influences compared to associations seen in unrelated individuals (19).

In our 40-year longitudinal twin cohort study (MOBILETWIN study) we have previously analyzed the long-term predictors of later life PA but have identified only mid-life smoking as a factor causally influencing later life PA (20). Much of the association between mid-life and later life PA was explained by shared genetic factors (20). As it is largely unknown how we can influence the genetically determined ageing process we now investigated how chronic disease conditions are associated with objectively measured PA and SB in community dwelling twins with mean age of 73 years. Specifically, we 1) first tested the validity of a simple question on diseases restricting mobility against other more specific questionnaire items. Next, 2) we analyzed how the question on disease-related mobility restrictions was associated with objectively measured PA and SB characteristics. Thirdly, 3) we studied how

other reported chronic diseases were associated with objectively measured PA and SB in addition to the self-reported disease-related mobility restrictions. Finally, 4) we analyzed whether members of DZ and MZ twin pairs discordant for self-reported diseases restricting mobility differed in their objectively measured PA and SB.

Materials and methods

This MOBILETWIN study (20) is an ancillary to the older Finnish Twin Cohort Study (21). Written informed consent was obtained from all participants. The study was approved by the Ethics Committee of the Hospital District of Southwest Finland on 20 May 2014.

Participant inclusion and study design

The study is based on a nationwide sample of all same-sex twin pairs born before 1958 with both co-twins alive in 1975 (21). A baseline questionnaire was sent to all twin candidates in 1975. Among those whose addresses could be identified (93.5% of subjects) in 1975, the response rate for twins was 87.6%. A subsequent questionnaire was mailed in 1981 to all the verified twins. The corresponding response rate among those responding in 1975 and alive in 1981 was 90.7%.

For the current PA study (MOBILETWIN), twins from the 1940 – 1944 birth cohorts were selected (Figure 1). Altogether 3 186 twin individuals belonged to these birth cohorts and had responded to at least one of the questionnaires (1975 or 1981). A total of 145 twin individuals were excluded because they had participated in one of the previous studies on psychiatric disorders (schizophrenia and bipolar studies). All remaining 816 (256 MZ, 490 DZ and 70 with unknown zygosity) complete twin pairs, i.e., both alive and contactable, were invited to

participate in the present study. The twins were sent an invitation letter in which they chose whether to participate in health and cognition telephone interview and/or accelerometer study completed with physical functioning questionnaire. Altogether 1012 (61.9%) twin individuals participated in the telephone interview, 791 twin individuals wore the accelerometer, and 817 individuals filled in the whole questionnaire on physical functioning. The target group of this analysis were those 779 individuals (276 complete twin pairs; 117 MZ, 143 DZ and 16 pairs with unknown zygosity) who participated in telephone interview, objective PA monitoring and responded to the question on diseases restricting mobility. So, of the 1614 individuals alive on the day of the follow-up, 140 were not contactable (not community dwelling) and of the remaining 1474 individuals 779 (53%) participated in all parts of this follow-up study with required responses (for more details see Figure 1). Data was collected during 2014 to 2016 starting from the oldest birth cohort. Accelerometer and questionnaire was mailed to each volunteering participants after the interview. The median time difference between the interview and accelerometer measurement was 17.5 days. According to the mid-life questionnaire data on PA, those who participated in this follow-up study and who did not participate had similar leisure-time PA levels (Waller et al. 2018), but at follow-up the target group was a selected community dwelling group as those less healthy individuals living in nursery homes were not contactable.

Physician-diagnosed diseases and mobility limitations

The participants were interviewed on their health and cognition and they responded to a questionnaire on mobility limitations. The questionnaire included a structured question ‘Do you have any physician-diagnosed disease which restricts your mobility?’ The response alternatives were ‘no’ and ‘yes’ followed by an open question on the disease restricting the mobility most. The questionnaire also included questions on whether the participant was able

to walk a distance of 2 km and whether the participant was able to climb one flight of stairs. In both of these structured questions there were five response alternatives (22) as follows: 1) able to manage without difficulty, 2) able to manage with some difficulty, 3) able to manage with great deal of difficulty, 4) able to manage only with help of another person, and 5) unable to manage even with help. Those responding to alternatives 2, 3, 4 or 5 were classified as having difficulty. We also asked the participants to estimate with 0.5 km accuracy how many kilometers altogether they have walked or jogged outside during the past 7 days. Our telephone interview and/or questionnaire included a list of common physician-diagnosed chronic diseases, which may compromise person's ability to be physically active. The interview included hypertension, coronary heart disease/myocardial infarction, stroke, peripheral arterial disease, heart failure, atrial fibrillation, diabetes, Parkinson's disease, dementia, depression and diseases causing visual impairments and the questionnaire included separate items for rheumatoid arthritis, knee osteoarthritis, hip osteoarthritis, osteoporosis and arterial disease causing claudication.Body mass index (BMI) was calculated based on self-reported (questionnaire) height and weight.

Accelerometer data collection

PA was measured with a hip-worn, light triaxial accelerometer (Hookie AM20, Traxmeet Ltd, Espoo). The device with the instructions for use was mailed to the participants, who were asked to use the accelerometer during waking hours (excluding activities in water) for 7 consecutive days. Participants mailed the device back to the UKK Institute for data analysis. The analysis of raw acceleration (milligravity; 1mg = 0.00981 m/s^2) data was based on novel algorithms that employ the mean amplitude deviation (MAD) of the resultant acceleration in 6 s epochs and the angle for posture estimation (APE) of the body, metrics that provide

consistent and accurate assessments of the intensity, volume and daily distribution for PA and separately the volume and its daily distribution for sedentary and stationary behaviors (23-25).

The MAD metric has been validated through directly measured incident oxygen uptake (VO_2) during walking or running on an indoor track (24). This strong association allowed for conversion of MAD values to incident energy consumption (MET). The MET were smoothed by calculating the one-minute exponential moving average of MAD values for each 6s epoch. According to recommended use (26) cut-points for different activities were set as 1.5-3 MET for light activities, 3-6 MET for moderate activities, and over 6 MET for vigorous activities, and corresponding mean daily total times were determined. As vigorous activity was low in this age-group, MVPA variable was constructed by summing up the time of moderate and vigorous activities. Mean daily sedentary time was defined as MET under 1.5 during lying down or sitting. Mean daily standing time was analyzed separately. Average daily step count and the most intensive 10-minute period of PA (Peak-10min MET) during the monitoring week were also documented. When determining the Peak-10min MET, the accelerometer value of each epoch is first converted to MET value. Then, the Peak-10min MET value is the highest 10 min moving average MET value of the measurement week.

Altogether, 791 twin individuals wore the accelerometer for at least 600 minutes per day for 4 days. Final target group for this study was those individuals (N=779, mean age 73 years, range 71 to 75 years) who participated in objective PA monitoring and also responded to the structured question: Do you have a physician diagnosed disease which restricts your mobility? On average, these 779 individuals wore the device for a mean of 6.73 (95% CI 6.69-6.77) days and mean 841 minutes (95% CI 835 –847 minutes) per day.

Statistical methods

First, bootstrapping (1000 samples) was used to calculate statistical significances when comparing the questionnaire item on diseases restricting mobility against other questionnaire items on mobility difficulties and PA level.

Our main analysis strategy was to investigate how much of the variation in PA was explained by the diseases, which the participants reported to restrict their mobility and to investigate whether reported chronic diseases not reported to restrict mobility were associated with low PA level also among those participants who did not report any mobility restricting disease. In addition, we analyzed the additional contribution of body-mass index in explaining the variation in PA.

Results were calculated with bootstrapping (1000 samples unless otherwise noted) and are given as medians and their 95% confidence intervals (CIs) (Stata 12.0; Stata Corp., College Station, TX, USA). We used linear regression analyses to define R squared (R^2) as a measure of variance accounted for. First, the analyses were done with twins treated as individuals; however, because of the clustering of twins within pairs (as the sampling unit was the twin pair), the observations obtained from twin pairs may be correlated, robust estimators of variance (the cluster option in Stata) were used (27). All basic analyses yielding R^2 values were adjusted for age and sex. Square root-transformation for MVPA and log-transformation for Peak-10min MET were used for regression analyses because these variables were not normally distributed. Pairwise analyses among twin pairs (all pairs, DZ pairs, and MZ pairs separately) were done using Wilcoxon matched-pairs signed-rank test to discover if pairs

discordant for reported diseases restricting mobility differed in the objectively measured PA or SB variables.

Results

The mean BMI of the participants was 26.11 kg/m^2 (SD 3.92) with 15.2% of the participants having a BMI over 30 kg/m^2.

Questionnaire reports on diseases restricting mobility and physical mobility limitations

Among the participants, nearly every fourth participant (23.2 %, 181 of 779) reported to have a disease that restricted their mobility. In the following open question the most common such diseases were musculoskeletal disease in 60.2% of cases (14% of all participants; osteoarthritis being the most common specific condition with 35.4% of the cases), followed by cardiovascular (18.8%), neurological (7.7%) and pulmonary (7.7%) diseases (Table I). Of the participants, almost every fifth (19.3%) reported at least some limitations in walking two kilometers. Among those who did not report diseases restricting mobility, 92.3% of participants reported no limitations in walking two kilometers while this proportion was 43.1% in participants reporting restricting diseases (P<0.0001). Nearly every fourth participant (23.3%) reported at least some limitations in stair climbing. Among those who did not report diseases restricting mobility, 95.6% reported no limitations in climbing stairs, compared with 63.3% in participants reporting mobility restricting diseases (P<0.0001).

Participants who reported having diseases restricting mobility reported their mean weekly distance of walking or jogging being 11.5 km (95% CI 9.9.-13.3 km) compared to 18.4 km (95% CI 17.2-19.6 km) in those reporting no restricting diseases (mean difference 6.9 km

(95% CI 4.7-9.1 km). As a validity test we calculated (using bootstrapping) the correlation between the reported weekly distance of walking or jogging and objectively measured daily steps the Pearson correlation being r=.61 (95% CI .55-.66; *P*<.0001).

Reported disease restricting mobility, other chronic diseases and objective physical activity measurement; individual-based analyses

Distributions of the PA and SB variables in the target cohort are shown in Supplementary Table I. Expectedly, among those who reported diseases restricting their mobility the objectively measured sedentary time (lying and sitting) was longer and both light physical activity (LPA) and MVPA were lower as were the daily steps compared with those reporting no such diseases (Table II). Also, the intensity of the most intensive 10 minute PA period during the measurement week (Peak-10min MET) was lower among those reporting mobility restricting diseases. The mean difference in daily MVPA was 18 min (95% CI 14 to 22 min) and in daily steps 2247 (95% CI 1746 to 2746 steps) in favour of those not reporting a disease restricting their mobility. All the differences were rather similar among men and women (Table II) except for standing time with borderline statistically significant sex interaction (*P*=0.050). There was no difference in the daily measurement time between the groups.

When looking at the physician-diagnosed diseases reported by the participants in the interview or questionnaire, expectedly there was substantial variation in the prevalence of the diseases by reporting any disease restricting mobility (Supplementary Table II). E.g., 44.0 % of those not reporting a disease restricting mobility reported having hypertension compared to 60.3 % among those reporting restricting disease. The corresponding percentages were 4.4% vs. 14.2% for heart failure and 14.4% vs. 40.9% for knee osteoarthritis (Supplementary Table II).

Using linear regression analysis we estimated how much the reported diseases accounted for the variation in the PA characteristics. With sex and age in the model, the reported disease restricting mobility explained 11.8% of the variation in MVPA and 10.4% of the variation in daily steps (Table III). When adding different self-reported diseases separately to the regression model, each of eight diseases (hypertension, coronary heart disease or myocardial infarction, heart failure, atrial fibrillation, diabetes, rheumatoid arthritis, knee osteoarthritis, hip osteoarthritis) increased the explanatory power in the variation of MVPA more than 0.1%. For the association between these selected reported diseases and MVPA see Supplementary Table III, and daily steps see Supplementary Table IV when the question on their mobility restrictions is ignored. In addition, increased number of reported diseases was associated with low physical activity (Supplementary Table V). After adding all these eight conditions to the previous model the fraction of variance accounted for increased to 18.5% for MVPA and 16.0% for daily steps. The explanatory fraction tended to be higher for women than men but the sex interaction was statistically non-significant (Table III). Adding BMI to the model further increased the fraction of variance accounted for MVPA to 25.5% and for daily steps to 20.7%. For results on other PA and SB variables, see Table III.

When we combined the above mentioned eight diseases common in the older individuals but not always considered as a disease restricting mobility, we found that participants reporting these diseases, also among the group who did not report diseases restricting their mobility, had lower MVPA, daily steps and other physical activity level indicators than participants not reporting these diseases (Supplementary Table VI).

Pairwise analysis

There were 100 (63 DZ, 32 MZ, 5 with unknown zygosity) same-sex twin pairs who were discordant for reported chronic diseases restricting their mobility (Table IV). Among these pairs the objectively measured MVPA was higher in co-twins not reporting diseases restricting mobility compared to their co-twins with restricting disease (pairwise difference in median daily MVPA 11 min for all pairs [P<0.001 for pairwise difference], 15 min for DZ pairs [P<0.001] and 5 min for MZ pairs [P=0.009]). Also for other PA and SB characteristics the differences were smaller for MZ than for DZ pairs (Table IV). SB was higher among the co-twins with restricting disease (P<0.001).

Discussion

Among community dwelling older men and women one fourth of the variation in objectively measured MVPA was explained by age, sex, body-mass index and self-reported diseases. These variables explained more of the variation in MVPA than that of the low intensity activity or SB. Diseases that the participants recognized as reducing mobility accounted for only part of the variability and adding other reported diseases to a regression model increased the explanatory power of the model. Hence, participants did not always recognize that their diseases were associated with low PA level.

Our study results are consistent with several earlier reports. The review by Brown and Flood (2) reported the risk factors most frequently identified as being independently associated with mobility limitation noted by five or more observational studies include older age, low PA, obesity, strength or balance impairments, and having chronic diseases such as diabetes or arthritis. Welmer et al. (3) found that body-mass index, coronary heart disease and heart failure are associated with mobility limitations. In addition to diseases, which according to

the participants' reports restrict their mobility, there were various common chronic diseases which associated with lower PA levels and increased sedentariness. In addition, higher number of diseases conditions associated with lower PA levels. Finally, we note that Smith et al. (28) found that chronic health status predicts nonparticipation in PA also after adjustment for self-reported health status. The associations of diseases with SB were weaker than those with PA, however, reducing SB may be an important and feasible way of maintaining mobility among aged with severe disease conditions.

In our study cohort we had questionnaire data on the leisure-time PA of the participants in mid-life (in 1975, 1980 and 1990) (20). The participants reporting diseases causing mobility restrictions at follow-up did not differ significantly in leisure-time PA in mid-life from those reporting no diseases restricting mobility at follow-up (for more details see Supplementary Table VII), supporting the direct relation between the development of disease and mobility restrictions. Pairwise analyses showed that in the co-twin control design the differences in PA variables were smaller among MZ than among DZ pairs discordant for self-reported diseases restricting mobility. This is consistent with the previous finding that genetic factors contribute to the etiology of physical activity limitations (20). These findings together also suggest that reverse causality analyses are needed in studies evaluating the associations between PA and occurrence of diseases (8).

It is important to pay attention to the declined fitness and PA level of older individuals, in particular if they have chronic diseases, as the slowly progressing diseases in the long-term are related with physical inactivity and further with physical disability. Either by maintaining PA levels or by using tailored exercise interventions (6,7) it is possible to improve the physical function of these individuals. In Finland, physicians are advised to recommend PA

for patients who have diabetes or other chronic diseases, which may attenuate the associations seen in this study, but obviously there is an urgent need to increase the exercise counselling of patients with chronic disease to both maintain mobility and slow the progression of the diseases (6,29).

Our results were also in agreement with the findings that overweight and obesity are associated with low PA and increased incidence of mobility limitations (30,31). There is accumulating data on that genetic pleiotropy may contribute to the co-existence of low PA, obesity and chronic disease (8,16,32). Our pairwise analyses also support the contribution of genetic pleiotropy contributing to the association between SB, PA and chronic disease, however, there was a difference in MVPA between the members of the disease-discordant MZ twin pairs. The contribution of genetic factors for physical activity level was shown by the previous finding that shared genetic factors explained most of the association between mid-life and later life PA levels (20). Also, there is the possibility for reverse causality, as some of the diseases such as hypertension do not cause immediate mobility limitations. Identifying chronic disease conditions and reductions in PA is most probably essential in identifying older risk persons needing preventive measures such as exercise-based rehabilitation to maintain their mobility.

The strengths of our study include sampling from a large and population-based twin cohort including men and women and successful modern objective monitoring of PA and SB characteristics. The limitations of our study include that our data on chronic diseases relied on self-reports although they had to be physician-diagnosed. In order to maximize the participation rate, the participants were not invited to travel to laboratory examinations, which means that we have not measured their body composition or physical function at

laboratory. Mobility limitations increase with increasing disease severity, but in our survey we were not able to do a severity classification of the diseases. At follow-up, all twins were community dwelling, therefore individuals with severe mobility limitations were rare, which needs to be taken into account when generalizing the results.

In conclusion, occurrence of chronic diseases is associated with low PA and individuals do not always recognize this. Different modes of exercise therapy have previously been shown to be effective in improving both measured and self-reported functioning (6) and further the independent mobility. Healthcare professionals should pay attention to low PA and mobility of individuals with chronic disease conditions before these cause limitations in independent living.

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Figure and Table legends

Figure 1. Study flow chart.

Table I. Self-reported physician-diagnosed diseases restricting most mobility among those 181 participants reporting a mobility restricting disease.

Table II. Daily physical activity and sedentary behavior characteristics according to self-reported physician-diagnosed diseases restricting mobility and sex.

Table III. Reported diseases and body-mass index explaining variation in daily physical activity/sedentary behaviour characteristics.

Table IV. Moderate-to-vigorous physical activity in twin pairs discordant for self-reported physician-diagnosed disease restricting mobility.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author, U.M.K., upon reasonable request.

Table I. Self-reported physician-diagnosed diseases restricting most mobility among those 181 participants reporting a mobility restricting disease.

Disease	N	%	% of all 779 participants
Musculoskeletal problems	109	60.2	14.0
Osteoarthritis	64	35.4	8.2
Rheumatoid arthritis	5	2.8	0.6
Other back-related	16	8.8	2.1
Other joint-related	8	4.4	1.0
Other musculoskeletal	16	8.8	2.1
Cardiovascular problems	34	18.8	4.4
Coronary heart disease or Myocardial infarction	10	5.5	1.3
Heart arrhythmia	9	5.0	1.2
Heart failure	4	2.2	0.5
Valvular disease	3	1.7	0.4
Other cardiovascular	8	4.4	1.0
Neurological problems	14	7.7	1.8
(Poly)neuropathy	5	2.8	0.6
Parkinson's disease	3	1.7	0.4
Stroke	3	1.7	0.4
Other neurological	3	1.7	0.4
Pulmonary disease	14	7.7	1.8
Asthma	7	3.9	0.9
COPD	5	2.8	0.6
Other pulmonary	2	1.1	0.3
Other	6	3.3	0.8
No response	4	2.2	0.5
Total	181	100	23.2

Table II. Daily physical activity and sedentary behavior characteristics according to self-reported physician-diagnosed diseases restricting mobility and sex.*

Activity/inactivity variable	Reported disease restricting mobility (n of persons)		
All **Men** **Women**	**No (n=598)** **(n=293)** **(n=305)**	**Yes (n=181)** **(n=85)** **(n=96)**	
	Median (95% CI of median)		***P* value**[†]
Sedentary time (lying and sitting)/day, min			
All	523 (514 to 532)	558 (545 to 574)	<.0001
Men	531 (520 to 550)	551 (529 to 588)	.001
Women	512 (501 to 526)	565 (544 to 590)	<.0001
Standing time/day, min			
All	86 (82 to 90)	70 (73 to 75)	<.0001
Men	79 (76 to 85)	73 (63 to 85)	.218
Women	91 (87 to 97)	67 (59 to 74)	<.0001
Time of light physical activity/day, min			
All	177 (171 to 182)	149 (145 to 160)	.003
Men	176 (170 to 184)	150 (145 to 170)	.028
Women	179 (165 to 183)	148 (134 to 165)	.042
Time of moderate-to-vigorous physical activity/day, min			
All	39 (37 to 43)	20 (17 to 25)	<.0001
Men	43 (37 to 47)	25 (18 to 32)	<.0001
Women	37 (34 to 39)	18 (13 to 24)	<.0001
Daily step count, number of steps			
All	6485 (6224 to 6742)	4085 (3680 to 4637)	<.0001
Men	6626 (6377 to 7117)	4442 (3805 to 5160)	<.0001
Women	6192 (5690 to 6711)	3812 (3145 to 4604)	<.0001
Peak-10min MET, MET			
All	3.65 (3.56 to 3.73)	2.99 (2.87 to 3.11)	<.0001
Men	3.67 (3.56 to 3.81)	3.10 (2.88 to 3.27)	<.0001
Women	3.60) (3.55 to 3.72)	2.92 (2.75 to 3.08)	<.0001

*All analyses with bootstrapping (1000). Activity variables calculated based on 1 minute exponential moving average.

[†]*P* values for the difference between those with mobility restricting disease and those without from linear regression analysis adjusted for sex, age and cluster for family.

Table III. Reported diseases and body-mass index explaining variation in daily physical activity/sedentary behaviour characteristics.

Activity/inactivity variable	R^2 values from different regression models			
	Model 1	**Model 2**	**Model 3**	**Model 4**
All	n = 789	n = 777	n = 762	n = 753
Men	n = 383	n = 376	n = 367	n = 363
Women	n = 406	n = 401	n = 395	n = 390
	R^2			
Sedentary time				
All	0.5%	5.5%	10.0%	13.0%
Men	1.1%	5.2%	10.1%	15.6%
Women	0.0%	6.0%	12.9%	13.8%
Standing time				
All	0.7%	3.1%	8.0%	15.2%
Men	1.7%	2.4%	8.8%	18.8%
Women	0.0%	4.7%	10.9%	15.5%
Light physical activity				
All	0.4%	1.7%	7.8%	10.2%
Men	0.0%	1.3%	7.7%	12.5%
Women	0.9%	2.3%	10.2%	11.2%
Moderate-to-vigorous physical activity				
All	2.0%	11.8%	18.5%	25.5%
Men	0.1%	6.6%	15.9%	27.0%
Women	0.0%	14.5%	21.3%	25.5%
Steps				
All	1.0%	10.4%	16.0%	20.7%
Men	0.1%	7.6%	14.2%	23.9%
Women	0.1%	11.4%	19.3%	20.5%
Peak-10min MET				
All	1.1%	12.0%	20.4%	27.8%
Men	0.0%	7.5%	18.9%	27.6%
Women	0.0%	15.9%	24.7%	30.7%

Model 1: Including sex and age.
Model 2: Including sex, age and self-reported mobility restricting disease.
Model 3. Including sex, age, self-reported mobility restricting disease and self-reported cardio-metabolic or arthritis diseases (hypertension, coronary heart disease/myocardial infarction, heart failure, atrial fibrillation, diabetes, rheumatoid arthritis, knee osteoarthritis, hip osteoarthritis).
Model 4. Including variables in model 3 and body-mass index.
All analyses with bootstrapping (1000) and including clustering for families. Activity variables calculated based on 1 minute exponential moving average.

Table IV. Daily physical activity and sedentary behavior in twin pairs discordant for self-reported physician-diagnosed disease restricting mobility.

	Mean time activity/day[a] hours:minutes:seconds Median (95% CI of median)		**Z, *P* value[c]**
	1 – No disease	**2 – Yes disease**	
Sedentary time (lying and sitting)/day, h:min:sec			
All twin pairs (n=100)	525 (506 - 554)	552 (538 - 589)	Z=3.566, *P*<0.001
DZ twin pairs (n=63)	519 (477 - 552)	558 (537 - 590)	Z=3.498, *P*<0.001
MZ twin pairs (n=32)	538 (514 - 587)	546 (520 - 623)	Z=0.729, *P*=0.466
Standing time/day, h:min:sec			
All twin pairs	89 (78 - 96)	70 (62 - 76)	Z=2.921, P=0.003
DZ twin pairs	85 (67 - 100)	70 (55 - 77)	Z=2.386, *P*=0.017
MZ twin pairs	93 (78 - 101)	75 (62 - 93)	Z=1.253, *P*=0.210
Time of light physical activity/day, h:min:sec			
All twin pairs	183 (157 - 197)	153 (146 - 175)	Z=2.482, *P*=0.013
DZ twin pairs	196 (172 - 215)	151 (145 - 186)	Z=2.971, *P*=0.003
MZ twin pairs	150 (132 - 181)	168 (141 - 189)	Z=0.729, *P*=0.466
Time of moderate-to-vigorous physical activity/day, min			
All twin pairs	33 (27 - 38)	22 (17 - 27)	Z=4.965, *P*<0.001
DZ twin pairs	32 (26 - 43)	17 (12 - 25)	Z=4.108, P<0.001
MZ twin pairs	32 (24 - 43)	28 (23 - 36)	Z=2.599, *P*=0.009
Daily step count, number of steps			
All twin pairs	6259 (5669 - 7167)	4510 (3986 - 5291)	Z=4.937, *P*<0.001
DZ twin pairs	6711 (5726 - 7983)	4220 (3403 - 5385)	Z=4.183, *P*<0.001
MZ twin pairs	5136 (4595 - 7406)	5041 (4103 – 6401)	Z=1.739, *P*=0.082
Peak-10min MET, MET			
All twin pairs	3.49 (3.28 – 3.82)	3.00 (2.89 – 3.15)	Z=4.910, *P*<0.001
DZ twin pairs	3.56 (3.23 – 3.83)	2.89 (2.73 – 3.02)	Z=4.142, *P*<0.001
MZ twin pairs	3.37 (3.22 – 4.11)	3.24 (3.09 – 3.40)	Z=2.281, *P*=0.023

[a]Descriptive analyses with bootstrapping (1000 samples unless otherwise noted)
[c]Z as absolute value and *P* by Wilcoxon matched-pairs signed-rank test

Chronic diseases and objectively monitored physical activity profile among aged individuals – a cross-sectional twin cohort study

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Supplentary files:

Supplementary Table I. Distribution of physical activity and sedentary behavior variables in the target cohort of 779 participants (293 men and 305 women).

Supplementary Table II. Self-reported physician-diagnosed diseases by reporting any disease restricting mobility.

Supplementary Table III. Daily moderate-to-vigorous physical activity according to self-reported disease.

Supplementary Table IV. Daily steps according to self-reported disease.

Supplementary Table V. Moderate-to vigorous physical activity and daily steps according to the number of self-reported diseases and sex.

Supplementary Table VI. Daily physical activity/inactivity characteristics according to self-reported physician-diagnosed diseases restricting mobility and other physician diagnosed diseases and sex.

Supplementary Table VII. Median of the mean MET-index from self-reported leisure-time physical activity in 1975, 1981 and 1990* according to self-reported physician-diagnosed diseases restricting mobility at follow-up and sex.

Supplementary Table I. Distribution of physical activity and sedentary behavior variables in the target cohort of 779 participants (293 men and 305 women).

Activity/inactivity variable	Median (IQR from 25% to 75%)
Sedentary time (lying and sitting)/day, min	
All	532 (466 to 595)
Men	540 (474 to 598)
Women	526 (454 to 583)
Standing time/day, min	
All	82 (57 to 113)
Men	78 (57 to 107)
Women	86 (57 to 119)
Time of light physical activity/day, min	
All	171 (133 to 214)
Men	172 (130 to 214)
Women	169 (134 to 211)
Time of moderate-to-vigorous physical activity/day, min	
All	35 (18 to 56)
Men	38 (21 to 63)
Women	31 (17 to 50)
Daily step count, number of steps	
All	5958 (4056 to 8516)
Men	6376 (4513 to 8754)
Women	5560 (3713 to 8261)
Peak-10min MET, MET	
All	3.46 (2.93 to 4.14)
Men	3.51 (2.99 to 4.20)
Women	3.43 (2.91 to 4.05)

*All analyses with bootstrapping (1000 repetitions). Activity variables calculated based on one minute exponential moving average.

Supplementary Table II. Self-reported physician-diagnosed diseases by reporting any disease restricting mobility.

Disease	% (n) individuals reporting the physician diagnosed disease			
	All participants	Reported the specific disease including in the cardio-metabolic or arthritis disease cluster*		
		Did not self-report a disease restricting mobility	Self-reported a disease restricting mobility	*P* value†
Hypertension	47.8 (369 of 772; ND 7)	44.0 (261)	60.3 (108)	.001
Coronary heart disease/MI	12.1 (93 of 769; ND 10)	8.8 (52)	23.2 (41)	<.001
Heart failure	6.6 (51 of 767; ND 12)	4.4 (26)	14.2 (25)	<.001
Atrial fibrillation	9.5 (73 of 769; ND 10)	7.3 (43)	16.9 (30)	.001
Diabetes	14.0 (108 of 772; ND 7)	11.8 (70)	21.2 (38)	.001
Rheumatoid arthritis	4.7 (37 of 779;ND 0)	2.7 (16)	11.6 (21)	<.001
Knee osteoarthritis	20.5 (160 of 779; ND 0)	14.4 (86)	40.9 (74)	<.001
Hip osteoarthritis	7.6 (59 of 779; ND 0)	4.5 (27)	17.7 (32)	<.001

ND; not defined (either unclear status or no response)

*Cardio-metabolic or arthritis disease cluster included hypertension, coronary heart disease/myocardial infarction, heart failure, atrial fibrillation, diabetes, rheumatoid arthritis, knee osteoarthritis, hip osteoarthritis.

†By χ^2 test.

Supplementary Table III. Daily moderate-to-vigorous physical activity according to self-reported disease.*

Disease	Moderate to vigorous physical activity, min		
	Without the disease	With the disease	
	n Median (95% CI of median)		*P* value†
Hypertension	403 39 (35 to 44)	369 29 (26 to 33)	<.0001
Coronary heart disease/MI	676 36 (34 to 38)	93 25 (18 to 32)	<.0001
Heart failure	716 36 (34 to 38)	51 18 (11 to 27)	<.0001
Atrial fibrillation	696 36 (34 to 38)	73 25 (18 to 30)	<.0001
Diabetes	664 36 (34 to 38)	108 25 (15 to 35)	<.0001
Rheumatoid arthritis	742 36 (33 to 37)	37 16 (11 to 27)	<.0001
Knee osteoarthritis	619 37 (34 to 39)	160 25 (21 to 29)	<.0001
Hip osteoarthritis	720 35 (33 to 37)	59 24 (17 to 35)	.001

*All analyses with bootstrapping (1000 samples unless otherwise noted). Activity variable calculated based on one minute exponential moving average

†*P* values for the difference between those with the disease and those without from linear regression analysis adjusted for sex, age and cluster for family.

Supplementary Table IV. Daily steps according to self-reported disease.*

Disease	N of steps		
	Without the disease	With the disease	
	n Median (95% CI of median)		*P* value†
Hypertension	403 6657 (6275 to 7148)	369 5186 (4857 to 5573)	<.0001
Coronary heart disease/MI	676 6180 (5890 to 6440)	93 4346 (3805 to 5050)	<.0001
Heart failure	716 6096 (5821 to 6374)	51 4008 (3233 to 4746)	<.0001
Atrial fibrillation	696 6036 (5758 to 6272)	73 4818 (4285 to 6231)	.002
Diabetes	403 6657 (6275 to 7148)	108 4827 (3988 to 5576)	<.0001
Rheumatoid arthritis	742 6039 (5758 to 6272)	37 3976 (2911 to 5760)	.004
Knee osteoarthritis	619 6156 (5869 to 6453)	160 5329 (4440 to 5767)	.005
Hip osteoarthritis	720 6029 (5759 to 6248)	59 4739 (3633 to 6334)	.017

*All analyses with bootstrapping (1000 samples unless otherwise noted). Activity variable calculated based on one minute exponential moving average

†*P* values for the difference between those with the disease and those without from linear regression analysis adjusted for sex, age and cluster for family.

Supplementary Table V. Moderate-to vigorous physical activity and daily steps according to the number of self-reported diseases and sex.*

Activity variable	Disease status†			
	No reported disease	1 reported disease	2 reported diseases	3 or more reported diseases
	N of persons in each cell			
All	n = 259	n = 246	n = 171	n = 103
Men	n = 122	n = 110	n = 89	n = 57
Women	n = 137	n = 136	n = 82	n = 46
	Median (95% CI)			
Moderate-to-vigorous physical activity, min				
All	43 (38 to 48)	37 (31 to 39)	30 (27 to 37)	15 (11 to 22)
Men	48 (40 to 56)	42 (36 to 44)	37 (30 to 48)	17 (11 to 24)
Women	39 (34 to 44)	31 (26 to 37)	27 (24 to 32)	13 (7 to 25)
Steps				
All	6975 (6431 to 7815)	6114 (5700 to 6610)	5475 (4979 to 5799)	3765 (3311 to 4405)
Men	7903 (6944 to 8439)	6236 (6058 to 6788)	5728 (5054 to 6544)	4056 (3544 to 4777)
Women	6236 (5847 to 7136)	5450 (4858 to 6656)	5374 (4795 to 5740)	3215 (2568 to 4405)

*All analyses with bootstrapping (1000 repetitions).

†Number of self-reported cardio-metabolic or arthritis disease cluster diseases (reported hypertension, coronary heart disease/myocardial infarction, heart failure, atrial fibrillation, diabetes, rheumatoid arthritis, knee osteoarthritis or hip osteoarthritis ignoring the reporting of mobility restricting disease).

Supplementary Table VI. Daily physical activity/inactivity characteristics according to self-reported physician-diagnosed diseases restricting mobility and other physician diagnosed diseases and sex.*

Activity variable	Disease status		
	No reported disease	Other reported disease†	Reported disease restricting mobility
	N of persons in each cell		
All Men Women	n = 240 n = 115 n = 125	n = 358 n = 178 n = 180	n = 181 n = 85 n = 96
	Median (95% CI)		
Sedentary time, min			
All	503 (482 to 519)	536 (524 to 548)	558 (545 to 574)
Men	514 (487 to 531)	549 (531 to 558)	551 (529 to 588)
Women	495 (466 to 518)	526 (508 to 543)	565 (544 to 590)
Standing time, min			
All	90 (85 to 96)	81 (77 to 89)	70 (63 to 75)
Men	83 (73 to 89)	78 (74 to 85)	73 (63 to 85)
Women	99 (91 to 108)	87 (78 to 93)	67 (59 to 74)
Light physical activity, min			
All	185 (180 to 195)	168 (159 to 176)	149 (145 to 160)
Men	190 (180 to 200)	169 (155 to 179)	150 (145 to 170)
Women	183 (177 to 194)	168 (159 to 181)	148 (134 to 165)
Moderate-to-vigorous physical activity, min			
All	45 (39 to 49)	37 (33 to 40)	20 (17 to 25)
Men	48 (41 to 57)	40 (36 to 44)	25 (18 to 32)
Women	41 (36 to 48)	34 (27 to 37)	18 (13 to 24)
Steps			
All	7145 (6518 to 7965)	6168 (5686 to 6519)	4085 (3680 to 4637)
Men	7823 (6710 to 8468)	6257 (5989 to 6597)	4442 (3805 to 5160)
Women	6475 (6024 to 7830)	5579 (5131 to 6711)	3812 (3145 to 4604)
Peak-10min MET			
All	3.79 (3.63 to 4.00)	3.56 (3.44 to 3.67)	2.99 (2.87 to 3.11)
Men	3.74 (3.51 to 4.08)	3.66 (3.47 to 3.81)	3.10 (2.88 to 3.27)
Women	3.88 (3.63 to 4.03)	3.44 (3.28 to 3.60)	2.92 (2.75 to 3.08)

*All analyses with bootstrapping (1000 repetitions). Activity variables calculated based on one minute exponential moving average

†Self-reported cardio-metabolic or arthritis disease cluster (reported hypertension, coronary heart disease/myocardial infarction, heart failure, atrial fibrillation, diabetes, rheumatoid arthritis, knee osteoarthritis or hip osteoarthritis but did not report mobility restricting disease).

Supplementary Table VII. Median of the mid-life mean MET-index from self-reported leisure-time physical activity in 1975, 1981 and 1990* according to self-reported physician-diagnosed diseases restricting mobility at follow-up and sex.†

Activity/inactivity variable	Reported disease restricting mobility (n of persons)		
All **Men** **Women**	**No (n=470)** **(n=215)** **(n=255)**	**Yes (n=139)** **(n=71)** **(n=68)**	
	Median (95% CI)		***P* value‡**
Mid-life leisure-time mean MET-index from years 1975, 1981 and 1990, MET-hours/day			
All	2.14 (1.94 to 2.29)	2.04 (1.63 to 2.37)	.167
Men	2.24 (2.02 to 2.63)	2.34 (1.57 to 2.74)	.375
Women	2.05 (1.80 to 2.29)	1.89 (1.48 to 2.24)	.301

*Previous physical activity habits were assessed from the cohort by questionnaires in 1975, 1981 and 1990. All three questionnaires enabled calculation of the leisure-time MET-index. The MET-index was expressed as the sum-score of leisure-time physical activity MET-hours per day. To estimate the mean volume of physical activity during the three baseline survey years, the average of the MET index values obtained in 1975, 1981, and 1990 was computed and termed mid-life mean MET-index (see Waller et al. 2018).

†All analyses with bootstrapping (1000).

‡*P* values for the difference between those with the disease and those without from linear regression analysis adjusted for sex, age and cluster for family.