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Association Between Accelerometer-Measured Physical Activity and Mobility Limitations in Twins

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Background: The associations between mobility limitations and device-measured physical activity are sparsely studied. In this study, these associations are studied among community-dwelling older twins. ***Methods:*** This cross-sectional study utilized data gathered in 2014–2016 for the MOBILETWIN study. Participants were twins born in Finland between 1940 and 1944 (774 participants, mean age 73 years). Physical activity was measured with a hip-worn accelerometer. Mobility limitations were assessed with a questionnaire. ***Results:*** Individual-level analyses revealed that physical activity was associated with mobility limitations. Participants with severe mobility limitations took 2,637 ($SD = 1{,}747$) steps per day, those with some mobility limitations 4,437 ($SD = 2{,}637$) steps, and those without mobility limitations 7,074 ($SD = 2{,}931$) steps ($p < .05$). The within-twin pair analyses revealed the same pattern for the 144 dizygotic twin pairs, but no associations were seen for the 117 monozygotic twin pairs. ***Conclusions:*** Accelerometer-measured physical activity and mobility limitations were associated in community-dwelling older adults. Genetic factors may explain some of the variations in physical activity. ***Significance:*** A personalized exercise program to promote increased physical activity should be provided for older adults who report mobility difficulties. Future research is needed to examine causality between physical activity and mobility limitations.

Keywords: device measurement, steps, mobility difficulties, genetics

Key Points

- There is an association between physical activity and mobility limitation among community-dwelling older adults.
- However, genetic factors may explain some of the variations in physical activity.

Physical activity helps individuals to maintain their mobility and function and overall health (American College of Sports Medicine et al., 2009). However, older adults tend to be physically inactive, and only a few meet the current physical activity recommendations (Sun et al., 2013). Low physical activity is a risk factor for mobility limitation (Brown & Flood, 2013). Physical activity is also a promising intervention to prevent mobility disability and decrease mobility loss (Mankowski et al., 2017; Stathi et al., 2022). The increasing number of older adults means that physical activity (Sun et al., 2013) and mobility limitation (Musich et al., 2018) are important topics in promoting healthy aging.

Physical activity is influenced by many factors, including genetics. Twin studies comparing the similarity of monozygotic and dizygotic twins have explained some of the variation in physical activity as due to familial and genetic effects. Heritability estimates based on twin and family studies have ranged widely from minor genetic effects to high heritability (Kujala et al., 2020; Stubbe et al., 2006; Zhang and Speakman, 2019). This wide variation may result from differences in the measures of physical activity used and sample sizes. Overall, there is evidence from both twin and molecular genetic studies that genetic factors seem to be associated with daily physical activity, and therefore, it is important to be able to control for genetic factors when studying physical activity and its associations with different health outcomes.

Mobility limitations are increasingly common in older adults, and it has been estimated that about one third of older adults have mobility limitations (Musich et al., 2018). Mobility limitations increase mortality (Frith et al. 2017) and hospitalization (Musich et al. 2018) and are also associated with decreased quality of life (Groessl et al., 2007). In addition, mobility limitation has been found to be a risk factor for falls (Mänty et al., 2010) and is often the earliest sign of functional decline (Brown & Flood, 2013). Although mobility limitations can be assessed in several ways, most studies have favored self-report measures (Chung et al., 2015). Moreover, self-report measures have been found to be

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predictive of mobility disability and are associated with performance-based measures (Mänty et al., 2007; Sciamanna et al. 2023).

Previous studies have shown that low physical activity is linked to mobility limitation (Glass et al., 2021; Jefferis et al., 2015; Loprinzi et al., 2014; Mankowski et al., 2017; Paterson and Warburton, 2010). These studies have measured physical activity using a self-report questionnaire (Paterson and Warburton, 2010) or accelerometers (Glass et al., 2021; Jefferis et al., 2015; Loprinzi et al., 2014; Mankowski et al., 2017). In accelerometer studies, the variables commonly used to describe physical activity are mean daily time spent on light physical activity and moderate-to-vigorous physical activity. Sedentary behavior and daily step counts have also been used. However, a limitation of these studies has been the use of only a few physical activity variables to describe physical activity in relation to mobility limitation. In addition, the influence of genetic factors on the association between physical activity and mobility limitation is relatively unknown.

The aim of this study was to assess the association between accelerometer-measured physical activity and sedentary behavior and self-reported mobility limitations. We are using a cotwin control study design to control for shared genetic and childhood environmental factors. Twin pairs share their childhood environment, and monozygotic twins are genetically identical at the sequence level, whereas dizygotic twins share, on average, 50% of their segregating genes. We hypothesized that participants without mobility limitations would be physically more active than participants with mobility limitations. We also hypothesized that genetic factors would explain some of the differences.

Methods

Study Participants

The study is based on the Older Finnish Twin Cohort and MOBILETWIN studies. For the Finnish Twin Cohort study, a nationwide sample of same-sex twin pairs born before 1958 with both cotwins alive in 1975 was recruited (Kaprio et al., 2019). A health questionnaire was sent to all twin candidates in 1975. The subsequent questionnaires were mailed in 1981 to the participating twins who were alive and resident in Finland. In 1990, the questionnaire was mailed to the participating twins born between 1930 and 1957.

The MOBILETWIN study investigated a subcohort of twin pairs born between 1940 and 1944 drawn from the Finnish Twin Cohort data. Of these, only the twin individuals who had answered at least one health questionnaire (1975 and/or 1981 and/or 1990) were selected for the study (Waller et al., 2018). A total of 1,632 twin individuals (816 complete twin pairs) who were both alive and contactable were invited to participate in the MOBILETWIN study. They were sent an invitation letter in which they chose whether to participate in the health and cognition interview and/or physical activity study, which comprised accelerometer monitoring for 1 week and a physical functioning questionnaire. The inclusion and exclusion criteria have been described in detail earlier (Waller et al., 2018).

The target group of the present study comprised those who had participated in the accelerometer monitoring and completed the whole physical functioning questionnaire, including information on mobility limitations. The final sample comprised the twins with data from all three sources: interview, accelerometer monitoring, and questionnaire. Thus, 774 community-dwelling participants (279 monozygotic twin individuals, 447 dizygotic twin individuals, and 48 twin individuals of unknown zygosity), including 277 complete same-sex twin pairs (117 monozygotic pairs and 144 dizygotic pairs), were included in the analyses. The sample contained 374 (48.3%) men and 400 (51.7%) women. The data had been collected from 2014 to 2016, starting with the oldest birth cohort.

Measurement of Physical Activity and Sedentary Behavior

Physical activity was measured with a triaxial hip-worn accelerometer (Hookie AM20, Traxmeet Ltd.). The accelerometer together with instructions for its use was mailed to all the participants who had given their written informed consent. Participants were instructed to carry the device for 7 consecutive days during waking hours and to remove it only when showering, swimming, or bathing. After this, the accelerometer was mailed back in a prepaid envelope to the UKK Institute for data analysis. Accelerometer measurements were performed in a mean of 3.4 weeks (*SD* 5.5) after the health and cognition telephone interview. The accelerometer data were only included if the accelerometer had been worn for at least 10 hr per day for 4 days. This criterion was met by 774 twin individuals. On average, the participants wore the device for 6.7 (*SD* 0.6) days for about 14 hr per day (4 participants used it for 4 days, 44 for 5 days, 103 for 6 days, and 618 for 7 days). Nonwear time was defined as the sum of all periods of at least 30 min of consecutive zero acceleration.

The analyses of the raw accelerometer data were based on validated algorithms that employed the mean amplitude deviation of the resultant acceleration in 6-s epochs and the angle of posture estimation of the body. Studies have shown that these metrics are valid for analyzing raw triaxial data from different brands of accelerometers. Together, these metrics provide about 90% accuracy in assessing the intensity, volume, and distribution of daily physical activity and separating sedentary and stationary behaviors (i.e., lying, sitting, and standing) from any physical activity behavior (Vähä-Ypyä, Vasankari, Husu, Mänttäri et al., 2015; Vähä-Ypyä, Vasankari, Husu, Suni, & Sievänen 2015, 2018).

Coincident mean amplitude deviation values and oxygen consumption have shown a strong association during walking and running on an indoor track (Vähä-Ypyä, Vasankari, Husu, Mänttäri et al., 2015). Mean amplitude deviation values were converted to metabolic equivalents (METs). The MET values were classified as follows: 1.5–3 METs = light physical activity, 3–6 METs = moderate physical activity, and >6 METs = vigorous physical activity. Sedentary activities were defined as MET levels below 1.5 while lying and sitting. Standing time was analyzed separately. Moderate-to-vigorous physical activity was calculated by summing the time spent in moderate and vigorous physical activity. Total physical activity was calculated by summing the time spent in light, moderate, and vigorous physical activity.

In this study, physical activity was described by the number of mean daily steps, the mean daily MET, and number of sit-to-stand transitions. Mean daily time spent in light physical activity, moderate-to-vigorous physical activity, total physical activity, standing, and sedentary behaviors was also determined. The mean time of daily vigorous physical activity in this study group was very low (0:00:58 hr:min:s, *SD* 0:04:00); therefore, vigorous and moderate times have not been assessed separately. The mean daily MET was the average of daily average MET values. Sedentary behaviors consisted of time spent lying and sitting.

Self-Reported Mobility Limitations

A structured questionnaire on physical functioning was used to collect data on mobility limitations. The questionnaire was sent to

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the participants together with the accelerometer. Participants were asked whether they had problems in walking 2 km and 0.5 km or climbing one flight of stairs. These questions on mobility were formulated as follows: "Do you have difficulty in … " with the response alternatives (a) able to manage without difficulty, (b) able to manage with some difficulty, (c) able to manage with a great deal of difficulty, (d) able to manage but only with help from someone, and (e) unable to manage even with help from someone.

Mobility difficulties were further categorized into three subgroups: (a) no mobility limitations (able to manage without difficulty), (b) some mobility limitations (able to manage with some difficulty), and (c) severe mobility limitations or unable (able to manage with a great deal of difficulty, able to manage but only with help from someone, and unable to manage even with help from someone). This subgrouping was based on a previously used categorization (Mänty et al., 2007).

Background Characteristics

Participants were asked about their health-related issues in the health and cognition telephone interview and physical functioning questionnaire. The questionnaire also asked about fall history (falls during the previous 12 months). Information on rheumatoid arthritis, knee and hip osteoarthritis, claudication, and osteoporosis was also collected by questionnaire along with self-reported physician-diagnosed diseases restricting mobility. The questionnaire also asked about vision problems restricting mobility. The question on vision problems was formulated as follows: "Do you have vision problems that restrict your mobility?" The response alternatives were (a) no; (b) yes, in low light; (c) yes, a little in good light; and (d) yes, a lot in good light. Responses were dichotomized into two categories: (a) no vision problems restricting mobility and (b) vision problems restricting mobility (Alternatives b–d). Information on living arrangements, which was also collected by a questionnaire, was dichotomized into two categories: (a) alone and (b) with someone (spouse, child, grandchild, sibling, relative, and someone else). Telephone assessment of dementia (Gatz et al., 2002), was used to collect data on cognition. Body mass index, which has been found to show good validity in this cohort (Tuomela et al., 2019), was calculated using self-reported data on weight and height.

Ethics

The MOBILETWIN study was approved by the Ethics Committee of the Hospital District of Southwest Finland on May 2014. Data were collected in accordance with the Declaration of Helsinki. All participants gave their written informed consent prior to enrollment in the study.

Statistical Analyses

Data analyses were conducted using IBM SPSS Statistics (version 26) and Stata IC (version 16). Participants' characteristics were described using means and *SD* or numbers and percentages.

Linear regression models were used in the individual-level analyses, in which the twins were treated as individuals. As the results for members of a twin pair may be correlated due to shared genes and environmental factors, a robust estimator of variance (the cluster option in Stata) was used. Within-twin pair analyses were done for all pairs together (monozygotic pairs, dizygotic pairs, and pairs with unknown zygosity together), and monozygotic or dizygotic pairs were also analyzed separately. In total, 447 dizygotic individuals (144 pairs) and 279 monozygotic individuals (117 pairs) were studied. Within-twin pair analyses were estimated using fixed-effects linear regression. For details on the use of such models in twin studies, see the paper by Rose et al. (2022).

For the regression analyses, two models were created. Model 1 was adjusted for age and sex (results not shown as Model 2 yielded similar but slightly attenuated results). Model 2 was further adjusted for body mass index, living arrangements, self-reported vision problems, diagnosed diseases restricting mobility, telephone assessment of dementia score, nonfaller/faller, and self-reported disease (rheumatoid arthritis, knee osteoarthritis, hip osteoarthritis, claudication, and/or osteoporosis). Regression coefficients with 95% confidence intervals for mobility limitation according to the accelerometer data on physical activity and sedentary behavior were reported. In the within-twin pair analyses, age and sex were naturally controlled for as the twins were of the same age and same sex.

To examine differences in physical activity between the three mobility limitation groups, Sidak's multiple comparison test was used. Wilcoxon signed-rank test was used in additional analyses when analyzing pairwise differences among twin pairs discordant for self-reported mobility limitations. Discordance was defined as one twin having any kind of difficulty in walking 2 km and/or 0.5 km and/or climbing up one flight of stairs while their cotwin did not have any kind of problems in those activities.

Results

The basic characteristics of the study sample by mobility limitation are shown in Table 1. Mean participant age was 73 years, and 52% of participants were women. Of the 774 participants, 602 reported no mobility limitations, 130 participants reported having some problems, and 42 participants reported severe problems in walking 2 km and/or 0.5 km and/or climbing one flight of stairs. The group without mobility limitations had lower mean body mass index, fewer self-reported physician-diagnosed diseases, fewer vision problems restricting mobility, and fewer cases of rheumatoid arthritis, knee and hip osteoarthritis, and claudication than those with some or severe limitations. At least one fall during the previous 12 months was reported by 118 (15%) participants. The group with severe mobility limitations contained the highest proportion (31%) of fallers compared with the groups with some (21%) or no (13%) mobility limitations.

Across all participants, sedentary time (mean 8:54:52) accounted for most of their total daily activities, with much less time spent in light or moderate-to-vigorous activity (Supplementary Table S1 [available online]). Physical activity and mobility limitation showed a clear association. Participants who reported no mobility limitations were more physically active than those reporting mobility limitations (Figure 1).

Physical Activity and Mobility Limitation: Individual-Level Analyses

The individual-level linear regression analyses (Model 2) revealed that mean daily steps, light physical activity, moderate-to-vigorous physical activity, total physical activity, sedentary behavior, standing, mean daily MET, and sit-to-stand transitions were statistically significantly associated with severe mobility limitation when compared with no mobility limitations, whereas having some mobility limitations was only associated with mean daily steps, moderate-to-vigorous physical activity, total physical activity, mean daily MET, and sit-to-stand transitions. For example, those who reported severe mobility limitations took 2,637 ($SD = 1{,}747$) steps per day, those with some mobility limitations took 4,437 ($SD = 2{,}637$) steps per day, and those without

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Table 1 Characteristics of Study Cohort by Mobility Limitation Level

Variable	No mobility limitations $n = 602$ (77.8%)	Some mobility limitations $n = 130$ (16.8%)	Severe mobility limitations $n = 42$ (5.4%)
Sex, *n* (%)			
Men	301 (80.5)	56 (15.0)	17 (4.5)
Women	301 (75.3)	74 (18.5)	25 (6.3)
Age (years), mean (*SD*)	72.9 (1.0)	72.9 (0.9)	72.8 (1.1)
BMI (kg/m^2), mean (*SD*)	25.4 (3.2)	28.5 (4.5)	29.3 (6.1)
Living arrangements, *n* (%)			
Alone	144 (23.9)	40 (30.8)	16 (38.1)
With someone	458 (76.1)	90 (69.2)	26 (61.9)
Self-reported physician-diagnosed disease restricting mobility, *n* (%)			
Yes	69 (11.6)	78 (60.9)	33 (80.5)
No	525 (88.4)	50 (39.1)	8 (19.5)
Self-reported vision problems restricting mobility, *n* (%)			
Yes	45 (7.5)	24 (18.6)	12 (28.6)
No	557 (92.5)	105 (81.4)	30 (71.4)
Self-reported diseases, *n* (%)			
Rheumatoid arthritis	17 (2.8)	14 (10.8)	7 (16.7)
Knee osteoarthritis	85 (14.1)	59 (45.4)	15 (35.7)
Hip osteoarthritis	25 (4.2)	22 (16.9)	9 (21.4)
Claudication	13 (2.2)	11 (8.5)	5 (11.9)
Osteoporosis	36 (6.0)	12 (9.2)	4 (9.5)
TELE score, mean (*SD*)	19.0 (1.2)	18.7 (1.4)	19.1 (1.3)
Nonfaller and faller, *n* (%)			
Nonfaller	516 (86.6)	99 (79.2)	27 (69.2)
Faller	80 (13.4)	26 (20.8)	12 (30.8)

Note. Living arrangements: alone or with someone, for example, spouse, child, grandchild, sibling, relative, or someone else. TELE score range 0–20; higher scores indicate better cognition. BMI = body mass index; TELE = telephone assessment of dementia.

mobility limitations took 7,074 ($SD = 2{,}931$) steps per day. The reference level in all analyses was no mobility limitation (Table 2).

Physical Activity and Mobility Limitation: Within-Twin Pair Analyses

In the within-twin pair linear regression analyses among all twins (Model 2, Table 2), all measured activity and sedentary variables were statistically significantly associated with severe mobility limitations when compared with no mobility limitations. When comparing some mobility limitations with no mobility limitations, moderate-to-vigorous physical activity was the only statistically significantly associated variable. In the dizygotic twins, mean daily steps, moderate-to-vigorous physical activity, total physical activity, mean daily MET, and sit-to-stand transitions were statistically significantly associated with severe mobility limitations, but no associations were seen with having some mobility limitations. In the monozygotic twins, no associations were observed between any physical activity variable and either level of the mobility limitations. For example, in dizygotic twins, those who reported severe mobility took 2,575 ($SD = 1{,}480$) steps per day, those with some mobility limitations took 4,526 ($SD = 2{,}707$) steps per day, and those without mobility limitations took 7,085 ($SD = 2{,}974$) steps per day. In monozygotic twins, the steps were 2,288 ($SD = 1{,}476$), 4,493($SD = 2{,}845$), and 7,029($SD = 2{,}993$), respectively. No mobility limitation was the reference level in all analyses (Table 2).

Additional analyses among 87 twin pairs discordant for mobility limitation showed similar results between all physical activity variables (Supplementary Table S2 [available online]). Statistically significant results were found among discordant dizygotic twin pairs in all physical activity variables ($p < .05$). Among monozygotic twin pairs, there was a statistically significant difference only in the mean daily MET variable.

Discussion

This study of Finnish community-dwelling older twins in their 70s indicates that self-reported mobility limitations are associated with accelerometer-measured physical activity and sedentary behavior. Participants with mobility limitations were less physically active than those without mobility limitations. This was found for all physical activity variables (mean daily steps, light physical activity, moderate-to-vigorous physical activity, total physical activity, standing, mean daily MET, and sit-to-stand transitions) in all mobility limitation groups, that is, no limitations, some limitations, and severe limitations. Participants with mobility limitations also engaged in more sedentary behavior than those without mobility limitations when all the participants were considered as

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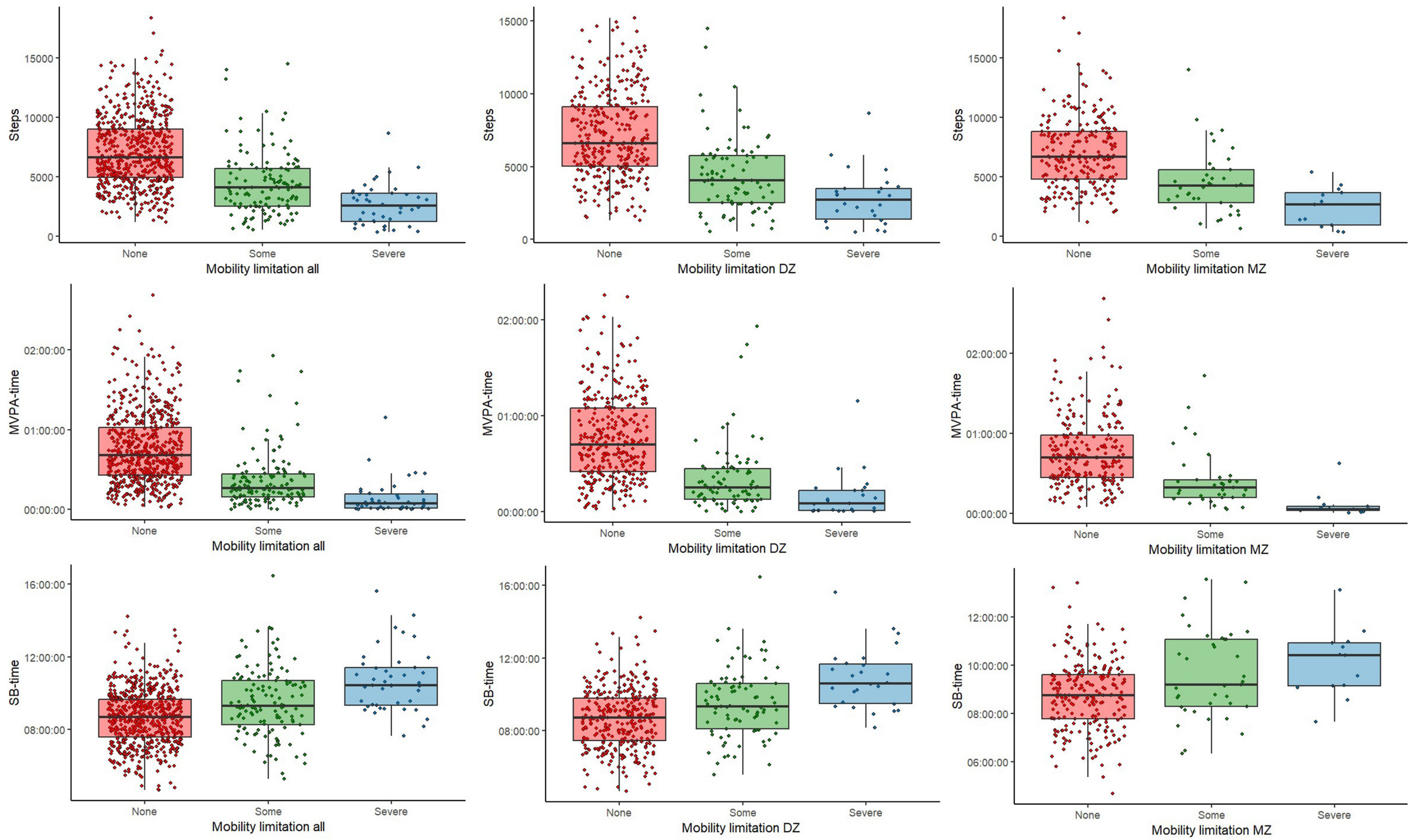

Figure 1 — Steps, MVPA, and sedentary behavior time by mobility limitation level in individual-level analyses and within-twin pair analyses. DZ = dizygotic twin, MZ = monozygotic twin; MVPA = moderate- to vigorous-intensity physical activity time.

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Table 2 Multivariate Adjusted Regression Coefficients of Physical Activity on Mobility Limitation

Level of PA and sedentary behavior[a] (mean daily)	Individual-level analyses (n = 774)		Within-twin pair analyses All (n = 277 pairs)		DZ (n = 144 pairs)		MZ (n = 117 pairs)	
	β	[95% CI]	β	[95% CI]	β	[95% CI]	β	[95% CI]
Steps								
Some mobility limitation	**−1676.59**	**[−2,330.72, −1,022.46]**	−924.73	[−1,859.97, −10.51	−716.82	[−1,964.21, 530.58]	−637.76	[−2,356.55, 1,081.04]
Severe mobility limitation	**−3096.44**	**[−3,932.70, −2,260.17]**	**−2446.42**	**[−3,934.92, −957.92]**	**−2417.20**	**[−4,242.70, −591.69]**	−1258.97	[−4,292.85, 1,774.90]
Light								
Some mobility limitation	−588.82	[−1,549.99, 372.36]	−149.15	[−1,233.36, 935.07]	542.86	[−858.93, 1,944.64]	−329.52	[−2,208.50, 1,549.46]
Severe mobility limitation	**−2178.41**	**[−3,439.51, −917.30]**	**−2063.56**	**[−3,789.18, −337.95]**	−2002.82	[−4,054.27, 48.63]	−818.66	[−4,135.27, 2,497.95]
Moderate to vigorous								
Some mobility limitation	**−887.29**	**[−1,216.70, −557.88]**	**−513.49**	**[−1,016.36, −10.63]**	−503.73	[−1,176.38, 168.93]	−192.68	[−1,104.34, 7,18.99]
Severe mobility limitation	**−1542.67**	**[−1,947.57, −1,137.78]**	**−1082.17**	**[−1,882.52, −281.83]**	**−1052.84**	**[−2,037.23, −68.44]**	−721.43	[−2,330.62, 887.77]
Total physical activity								
Some mobility limitation	**−1476.11**	**[−2,530.69, −421.53]**	−662.64	[−1,830.86, 505.58]	39.13	[−1,507.28, 1,585.55]	−522.20	[−2,530.61, 1,486.21]
Severe mobility limitation	**−3721.08**	**[−5,077.23, −2,364.93]**	**−3145.74**	**[−5,005.04, −1,286.43]**	**−3055.65**	**[−5,318.77, −792.54]**	−1540.09	[−5,085.17, 2,004.99]
Sedentary behavior								
Some mobility limitation	1033.67	[−394.35, 2,461.70]	−51.00	[−1,925.95, 1,823.95]	−571.39	[−3,115.56, 1,972.78]	−281.52	[−3,561.88, 2,998.84]
Severe mobility limitation	**4393.21**	**[2087.59, 6698.83]**	**3534.55**	**[550.43, 6,518.68]**	3409.77	[−313.51, 7,133.05]	880.83	[−4,909.38, 6,671.03]
Standing								
Some mobility limitation	−386.52	[−968.01, 194.97]	257.53	[−620.09, 1,135.14]	158.87	[−1,074.27, 1,392.02]	204.96	[−1,317.39, 1,727.32]
Severe mobility limitation	**−1490.33**	**[−2,396.44, −584.23]**	**−1538.60**	**[−2,935.39, −141.82]**	−1647.32	[−3,451.97, 157.33]	−495.32	[−3,182.46, 2,191.82]
Mean daily MET								
Some mobility limitation	**−0.07**	**[−0.10, −0.04]**	−0.04	[−0.08, 0.00]	−0.03	[−0.08, 0.03]	−0.02	[−0.09, 0.05]
Severe mobility limitation	**−0.14**	**[−0.18, −0.10]**	**−0.10**	**[−0.16, −0.04]**	**−0.09**	**[−0.17, −0.01]**	−0.05	[−0.18, 0.07]
Sit-to-stand transitions								
Some mobility limitation	**−3.84**	**[−7.17, −0.52]**	−0.80	[−5.39, 3.79]	−1.00	[−7.71, 5.71]	−0.07	[−7.29, 7.44]
Severe mobility limitation	**−10.21**	**[−15.51, −4.91]**	**−12.40**	**[−19.70, −5.09]**	**−14.45**	**[−24.27, −4.63]**	−3.16	[−16.16, 9.83]

Note. PA = physical activity; MET = metabolic equivalent; DZ = dizygotic twin, MZ = monozygotic twin; Total PA = moderate, vigorous, and light physical activity altogether; All pairs = dizygotic twin pairs, monozygotic twin pairs, and unknown zygotic twin pairs altogether; BMI = body mass index.

[a]According to linear regression, reference level is no mobility limitation. Model is adjusted for sex, age, BMI in 2016, living arrangements, self-reported vision problem, diagnosed disease restricting mobility, TELE score, nonfaller/faller, and self-reported disease (rheumatoid arthritis, knee osteoarthritis, hip osteoarthritis, claudication, and/or osteoporosis). Thirty-six participants who had missing data in one or more covariates were excluded from the individual-level analyses. Twenty-seven participants who had missing data in one or more covariates were excluded from the within-twin pair all pairs analyses. Fifteen participants who had missing data in one or more covariates were excluded from within-twin pair dizygotic pairs analyses. Seven participants who had missing data in one or more covariates were excluded from the within-twin pair monozygotic pair analyses.

The results written in bold are statistically significant ($^{*}p < .05$).

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individuals. In the dizygotic pairs, within-pair associations were similar, whereas in the monozygotic pairs, they were strongly attenuated.

Our results are in line with those reported by earlier studies of accelerometer-measured physical activity (Glass et al., 2021; Jefferis et al., 2015; Loprinzi et al., 2014; Mankowski et al., 2017). Glass et al. (2021) studied the association between light physical activity and incident mobility disability among older women and found that increased time spent in light physical activity was associated with reduced incident mobility disability. Jefferis et al. (2015) examined the association between physical activity and falls and also the modifying effect of mobility limitation. Analysis of their cross-sectional data set revealed that men with mobility limitations were less active than men without mobility limitations. The cross-sectional cohort study by Loprinzi et al. (2014) included both men and women. They found that those with mobility limitations, compared with those without, engaged in less light physical activity and moderate-to-vigorous physical activity and had more sedentary time. In their follow-up study, Mankowski et al. (2017) examined the association between accelerometer-measured physical activity and the incidence of major mobility disability and persistent major mobility disability. They found that steps and sedentary behavior were associated with both mobility disability incidences. Our cohort, in turn, included both sexes, and we assessed physical activity with a more comprehensive set of variables (mean daily steps, light physical activity, moderate-to-vigorous physical activity, total physical activity, standing time, mean daily MET, and sit-to-stand transitions) as well as sedentary behavior.

Previous studies have been conducted with individuals, whereas our sample consisted wholly of twins. This data set allowed us to control for genetic factors in addition to conducting analyses on twin individuals. The within-twin pair analyses of the dizygotic twin data yielded similar associations between physical activity and severe mobility limitation as was seen in individual-level analysis, although the effect size was somewhat weaker. The monozygotic twin data showed that the association and effect sizes of any physical activity variable with any mobility limitation level were markedly attenuated. This can be also seen in our pairwise analyses comparing twins discordant for self-reported mobility limitations (Supplementary Table S2 [available online]). Our results resemble previous findings on self-reported fitness and device-measured physical activity profiles. The physical activity differences between the members of monozygotic pairs were smaller than those between the members of dizygotic pairs (Waller et al., 2019). As shown previously, genetic factors may explain some of these variations in physical activity (Kujala et al., 2020; Stubbe et al., 2006; Zhang and Speakman, 2019), which can explain our results that differences were not seen in the associations among monozygotic twins. It should be noted that the present monozygotic twin sample size was rather small.

In this study, 22% of the participants reported difficulty in walking 2 km and/or 0.5 km and/or climbing one flight of stairs. In previous studies, around 30% of participants (range 22.5%–46.7%) have had mobility difficulties (Musich et al., 2018). Our lower prevalence of mobility limitations may partially result from our methods of assessment. However, questionnaires have previously been found to be associated with performance-based measures (Mänty et al., 2007; Sciamanna et al. 2023). Overall, assessment methods have varied. Sex also has an influence on the incidence of mobility limitation: Women have reported more mobility difficulties than men (Loprinzi et al., 2014). In our study, 58% of the participants who reported mobility limitations were women and 42% men. This distribution resembles that found by Loprinzi et al. (2014). Furthermore, our participants were relatively young community-dwelling older adults who probably had relatively good functional ability.

The group of participants with mobility limitations contained more fallers than the group without mobility limitations. This result is similar to other studies (Jefferis et al., 2015; Musich et al., 2018). The difference in physical activity between nonfallers and fallers who did not need fall-related healthcare was, however, minor. This indicates that physical activity did not necessarily decrease because of the fall. However, physical activity was lower among the fallers who needed health care (results not shown). This could be a result of the fall, possibly an injury, or fear of falling (Jefferis et al., 2014), or their physical activity may have already been low before the fall. Participants with mobility limitations reported relatively more often mobility-restricting physician-diagnosed diseases and rheumatoid arthritis, knee and hip osteoarthritis, claudication, and osteoporosis, any of which may have affected their physical activity. An association has been found between mobility-restricting physician-diagnosed diseases and physical activity and also between common chronic diseases and physical activity (Kujala et al., 2019).

Limitations and Strengths

One limitation of the study is the cross-sectional design as it does not allow us to draw any conclusions about the direction of causality. Notably, the participants who reported mobility limitations also reported more mobility-restricting physician-diagnosed diseases, rheumatoid arthritis, knee and hip osteoarthritis, claudication, and osteoporosis. Although we adjusted our analyses with several covariates, we were unable to take all the possible confounding factors, such as socioeconomic status and pain, into account. Although accelerometers have been found to be valid and objective tools for measuring physical activity (Vähä-Ypyä, Vasankari, Husu, Mänttäri et al., 2015, Vähä-Ypyä, Vasankari, Husu, Suni, & Sievänen 2015, 2018) that overcome many of the limitations of self-report data (Evenson et al., 2011), they have their limitations (Evenson et al., 2011; Schrack et al., 2016), including a limited ability to detect specific types of nonimpact activities like cycling, swimming, and yoga (Schrack et al., 2016). However, as walking is the most popular type of physical activity among older adults (Chaudhury et al., 2016), we considered it reasonable to assume that our participants' physical activity primarily consisted of walking rather than nonimpact activities. Using absolute intensity cut points corresponding to 3 METs and 6 METs may not accurately reflect the perceived activity levels of older adults and might potentially lead to underestimation of time spent in moderate and vigorous physical activity among older adults (Vähä-Ypyä et al., 2022). However, these absolute cut points have been used in most studies and enable comparisons across different population groups and different studies. Notably, most of the participants were born during World War II. This may have affected nutrition of participants and their mothers. Maternal undernutrition during gestation (De Rooij et al., 2022) and undernutrition in early life (De Sanctis et al., 2021) might have an effect on health in later life.

To our knowledge, this is the first study to examine the association between accelerometer-measured physical activity and self-reported mobility limitation in older twins, which enabled us to appraise genetic influences. Another strength of this study is the use of an accelerometer to measure physical activity as self-report

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physical activity questionnaires may not yield reliable and valid outcomes (Silsbury et al., 2015). Accelerometers enable valid measurement of several attributes of physical activity and sedentary behavior (Vähä-Ypyä, Vasankari, Husu, Mänttäri et al., 2015, Vähä-Ypyä, Vasankari, Husu, Suni, & Sievänen 2015, 2018). Mobility limitations can be assessed in various ways, including questionnaires (Chung et al., 2015). Subjective self-reported difficulty has been found to be a valid and reliable method for ascertaining mobility limitations (Brown & Flood, 2013). The present questionnaire included items on three mobility tasks (walking 2 km, walking 0.5 km, and climbing one flight of stairs). This structured questionnaire has been found to be a valid measure of mobility (Mänty et al., 2007). In addition, the present sample size was relatively large and representative of both sexes.

Conclusions

This study provided cross-sectional evidence of an association between physical activity and mobility limitation among community-dwelling older adults. Older adults who report mobility difficulties should be offered personalized physical activity guidance and programs to prevent the progress of mobility limitations. Future research is needed to examine causality between physical activity and mobility limitations and between sedentary behavior and mobility limitations.

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References

American College of Sports Medicine, Chodzko-Zajko, W.J., Proctor, D.N., Fiatarone Singh, M.A., Minson, C.T., Nigg, C.R., Salem, G.J., & Skinner, J.S. (2009). Exercise and physical activity for older adults. *Medicine & Science in Sports & Exercise, 41*, 1510–1530. https://doi.org/10.1249/MSS.0b013e3181a0c95c

Brown, C.J., & Flood, K.L. (2013). Mobility Limitation in the older patient: A clinical review. *JAMA, 310*, 1168–1177. https://doi.org/10.1001/jama.2013.276566

Chaudhury, H., Campo, M., Michael, Y., & Mahmood, A. (2016). Neigbourhood environment and physical activity in older adults. *Social Science & Medicine, 149*, 104–113. https://doi.org/10.1016/j.socscimed.2015.12.011

Chung, J., Demiris, G., & Thompson, H.J. (2015). Instruments to assess mobility limitation in community-dwelling older adults: A systematic review. *Journal of Aging and Physical Activity, 23*, 298–313. https://doi.org/10.1123/japa.2013-0181

De Rooij, S.R., Bleker, L.B., Painter, R.C., Ravelli, A.C., & Roseboom, T.J. (2022). Lessons learned from 25 years of research into long term consequences of prenatal exposure to the Dutch famine 1944–45: The Dutch famine birth cohort. *International Journal of Environmental Health Research, 32*, 1432–1446. https://doi.org/10.1080/09603123.2021.1888894

De Sanctis, V., Soliman, A., Alaaraj, N., Ahmed, S., Alyafei, F., & Hamed, N. (2021). Early and long-term consequences of nutritional stunting: From childhood to adulthood. *Acta Biomedica, 92*, Article e2021168. https://doi.org/10.23750/abm.v92i1.11346

Evenson, K.R., Buchner, D.M., & Morland, K.B. (2011). Objective measurement of physical activity and sedentary behavior among US adults aged 60 years or older. *Preventing Chronic Disease, 9*, Article E26.

Frith, E., Addoh, O., Mann, J.R., Windham, B.G., & Loprinzi, P.D. (2017). Individual and combined associations of cognitive and mobility limitations on mortality risk in older adults. *Mayo Clinic Proceedings, 92*, 1494–1501. https://doi.org/10.1016/j.mayocp.2017.06.019

Gatz, M., Reynolds, C.A., John, R., Johansson, B., Mortimer, J.A., & Pedersen, N.L. (2002). Telephone screening to identify potential dementia cases in a population-based sample of older adults. *International Psychogeriatrics, 14*, 273–289. https://doi.org/10.1017/S1041610202008475

Glass, N.L., Bellettiere, J., Jain, P., LaMonte, M.J., & LaCroix, A.Z. (2021). Evaluation of light physical activity measured by accelerometry and mobility disability during a 6-year follow-up in older women. *JAMA Network Open, 4*, Article e210005. https://doi.org/10.1001/jamanetworkopen.2021.0005

Groessl, E.J., Kaplan, R.M., Rejeski, W.J., Katula, J.A., King, A.C., Frierson, G., Glynn, N.W., Hsu, F-C., Walkup, M., & Pahor, M. (2007). Health-related quality of life in older adults at risk for disability. *American Journal of Preventive Medicine, 33*, 214–218. https://doi.org/10.1016/j.amepre.2007.04.031

Jefferis, B.J., Iliffe, S., Kendrick, D., Kerse, N., Trost, S., Lennon, L.T., Ash, S., Sartini, C., Morris, R.W., Wannamethee, S.G., & Whincup, P.H. (2014). How are falls and fear of falling associated with objectively measured physical activity in a cohort of community-dwelling older men?. *BMC Geriatrics, 14*, Article 114. https://doi.org/10.1186/1471-2318-14-114

Jefferis, B.J., Merom, D., Sartini, C., Wannamethee, S.G., Ash, S., Lennon, L.T., Iliffe, S., Kendrick, D., & Whincup, P.H. (2015). Physical activity and falls in older men: The critical role of mobility limitations. *Medicine & Science in Sports & Exercise, 47*, 2119–2128. https://doi.org/10.1249/MSS.0000000000000635

Kaprio, J., Bollepalli, S., Buchwald, J., Iso-Markku, P., Korhonen, T., Kovanen, V., Kujala, U., Laakkonen, E.K., Latvala, A., Leskinen, T., Lindgren, N., Ollikainen, M., Piirtola, M., Rantanen, T., Rinne, J., Rose, R.J., Sillanpää, E., Silventoinen, K., Sipilä, S., Viljanen, A., Vuoksimaa, E., & Waller, K. (2019). The older Finnish twin cohort - 45 years of follow-up. *Twin Research and Human Genetics, 22*, 240–254. https://doi.org/10.1017/thg.2019.54

Kujala, U.M., Hautasaari, P., Vähä-Ypyä, H., Waller, K., Lindgren, N., Iso-Markku, P., Heikkilä, K., Rinne, J., Kaprio, J., & Sievänen, H. (2019). Chronic diseases and objectively monitored physical activity profile among aged individuals – A cross-sectional twin cohort study. *Annals of Medicine, 51*, 78–87. https://doi.org/10.1080/07853890.2019.1566765

Kujala, U.M., Palviainen, T., Pesonen, P., Waller, K., Sillanpää, E., Niemelä, M., Kangas, M., Vähä-Ypyä, H., Sievänen, H., Korpelainen, R., Jämsä, T., Männikkö, M., & Kaprio, J. (2020). Polygenic risk scores and physical activity. *Medicine & Science in Sports & Exercise, 52*, 1518–1524. https://doi.org/10.1249/MSS.0000000000002290

Loprinzi, P.D., Sheffield, J., Tyo, B.M., & Fittipaldi-Wert, J. (2014). Accelerometer-determined physical activity, mobility disability, and health. *Disability and Health Journal, 7*, 419–425. https://doi.org/10.1016/j.dhjo.2014.05.005

Mankowski, R.T., Anton, S.D., Axtell, R., Chen, S-H., Fielding, R.A., Glynn, N.W., Hsu, F-C., King, A.C., Layne, A.S., Leeuwenburgh, C.,

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Manini, T.M., Marsh, A.P., Pahor, M., Tudor-Locke, C., Conroy, D.E., & Buford, T.W. (2017). Device-measured physical activity as a predictor of disability among mobility-limited older adults. *Journal of the American Geriatrics Society, 65*, 2251–2256. https://doi.org/10.1111/jgs.15037

Mänty, M., Heinonen, A., Leinonen, R., Törmäkangas, T., Sakari-Rantala, R., Hirvensalo, M., von Bonsdorff, M.B., & Rantanen, T. (2007). Construct and predictive validity of a self-reported measure of preclinical mobility limitation. *Archives of Physical Medicine and Rehabilitation, 88*, 1108–1113. https://doi.org/10.1016/j.apmr.2007.06.016

Mänty, M., Heinonen, A., Viljanen, A., Pajala, S., Koskenvuo, M., Kaprio, J., & Rantanen, T. (2010). Self-reported preclinical mobility limitation and fall history as predictors of future falls in older women: Prospective cohort study. *Osteoporosis International, 21*, 689–693. https://doi.org/10.1007/s00198-009-0950-x

Musich, S., Wang, S.S., Ruiz, J., Hawkins, K., & Wicker, E. (2018). The impact of mobility limitations on health outcomes among older adults. *Geriatric Nursing, 39*, 162–169. https://doi.org/10.1016/j.gerinurse.2017.08.002

Paterson, D.H., & Warburton, D.E. (2010). Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. *The International Journal of Behavioral Nutrition and Physical Activity, 7*, Article 38. https://doi.org/10.1186/1479-5868-7-38

Rose, R.J., Latvala, A., Silventoinen, K., & Kaprio, J. (2022). Alcohol consumption at age 18–25 and number of children at a 33-year follow-up: Individual and within-pair analyses of Finnish twins. *Alcoholism: Clinical and Experimental Research, 46*, 1552–1564. https://doi.org/10.1111/acer.14886

Schrack, J.A., Cooper, R., Koster, A., Shiroma, E.J., Murabito, J.M., Rejeski, W.J., Ferrucci, L.,& Harris, T.B. (2016). Assessing daily physical activity in older adults: Unraveling the complexity of monitors, measures, and methods. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 71*, 1039–1048. https://doi.org/10.1093/gerona/glw026

Sciamanna, C.N., Lemaster, K.A., Danilovich, M.K., Conroy, D.E., Schmitz, K.H., Silvis, M., Ladwig, M., & Ballentine, N. (2023). Accuracy of self-reported physical capacities as a clinical screening test for older adults with mobility disability. *Gerontology and Geriatric Medicine, 9*. https://doi.org/10.1177/23337214231167979

Silsbury, Z., Goldsmith, R., & Rushton, A. (2015). Systematic review of the measurement properties of self-report physical activity questionnaires in healthy adult populations. *BMJ Open, 5*, Article e008430. https://doi.org/10.1136/bmjopen-2015-008430

Stathi, A., Greaves, C.J., Thompson, J.L., Withall, J., Ladlow, P., Taylor, G., Medina-Lara, A., Snowsill, T., Gray, S., Green, C., Johansen-Berg, H., Sexton, C.E., Bilzon, J.L.J., deKoning, J., Bollen, J.C., Moorlock, S.J., Western, M.J., Demnitz, N., Seager, P., Guralnik, J.M., Rejeski, W.J., Hillsdon, M., & Fox, K.R. (2022). Effect of a physical activity and behaviour maintenance programme on functional mobility decline in older adults: The REACT (Retirement in Action) randomised controlled trial. *Lancet Public Health, 7*, e316–e326. https://doi.org/10.1016/S2468-2667(22)00004-4

Stubbe, J.H., Boomsma, D.I., Vink, J.M., Cornes, B.K., Martin, N.G., Skytthe, A., Kyvik, K.O., Rose, R.J., Kujala, U.M., Kaprio, J., Harris, J.R., Pedersen, N.L., Hunkin, J., Spector, T.D., & de Geus, E.J.C. (2006). Genetic influences on exercise participation in 37.051 twin pairs from seven countries. *PLoS One, 1*, Article e22. https://doi.org/10.1371/journal.pone.0000022

Sun, F., Norman, I.J., & While, A.E. (2013). Physical activity in older people: A systematic review. *BMC Public Health, 13*, Article 449. https://doi.org/10.1186/1471-2458-13-449

Tuomela, J., Kaprio, J., Sipilä, P.N., Silventoinen, K., Wang, X., Ollikainen, M., & Piirtola, M. (2019). Accuracy of self-reported anthropometric measures — Findings from the Finnish twin study. *Obesity Research & Clinical Practice, 13*, 522–528. https://doi.org/10.1016/j.orcp.2019.10.006

Vähä-Ypyä, H., Husu, P., Suni, J., Vasankari, T., & Sievänen, H. (2018). Reliable recognition of lying, sitting, and standing with a hip-worn accelerometer. *Scandinavian Journal of Medicine & Science in Sports, 28*, 1092–1102. https://doi.org/10.1111/sms.13017

Vähä-Ypyä, H., Sievänen, H., Husu, P., Tokola, K., Mänttäri, A., Heinonen, O. J., Heiskanen, J., Kaikkonen, K. M., Savonen, K., & Vasankari, T. (2022). How adherence to the updated physical activity guidelines should be assessed with accelerometer?. *The European Journal of Public Health, 32*(Suppl. 1), i50–i55. https://doi.org/10.1093/eurpub/ckac078

Vähä-Ypyä, H., Vasankari, T., Husu, P., Mänttäri, A., Vuorimaa, T., Suni, J., & Sievänen, H. (2015). Validation of cut-points for evaluating the intensity of physical activity with accelerometry-based mean amplitude deviation (MAD). *PLoS One, 10*, Article e0134813. https://doi.org/10.1371/journal.pone.0134813

Vähä-Ypyä, H., Vasankari, T., Husu, P., Suni, J., & Sievänen, H. (2015). A universal, accurate intensity-based classification of different physical activities using raw data of accelerometer. *Clinical Physiology and Functional Imaging, 35*, 64–70. https://doi.org/10.1111/cpf.12127

Waller, K., Vähä-Ypyä, H., Lindgren, N., Kaprio, J., Sievänen, H., & Kujala, U.M. (2019). Self-reported fitness and objectively measured physical activity profile among older adults: A twin study. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 74*, 1965–1972. https://doi.org/10.1093/gerona/gly263

Waller, K., Vähä-Ypyä, H., Törmäkangas, T., Hautasaari, P., Lindgren, N., Iso-Markku, P., Heikkilä, K., Rinne, J., Kaprio, J., Sievänen, H., & Kujala, U.M. (2018). Long-term leisure-time physical activity and other health habits as predictors of objectively monitored late-life physical activity – A 40-year twin study. *Scientific Reports, 8*, Article 9400. https://doi.org/10.1038/s41598-018-27704-7

Zhang, X., & Speakman, J.R. (2019). Genetic factors associated with human physical activity: Are your genes too tight to prevent you exercising? *Endocrinology, 160*, 840–852. https://doi.org/10.1210/en.2018-00873

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