Author(s): Skantz, Heidi; Rantalainen, Timo; Karavirta, Laura; Rantakokko, Merja; Palmberg, Lotta; Portegijs, Erja; Rantanen, Taina

Title: Associations Between Accelerometer-Based Free-Living Walking and Self-Reported Walking Capability Among Community-Dwelling Older People

Year: 2021

Version: Accepted version (Final draft)

Associations between Accelerometer-Based Free-Living Walking and Self-Reported Walking Capability among Community-Dwelling Older People

Heidi Skantz[1], MSc, Timo Rantalainen[1], PhD, Laura Karavirta[1], PhD, Merja Rantakokko[2], PhD, Lotta Palmberg[1], MSc, Erja Portegijs[1], PhD, Taina Rantanen[1], PhD

[1]Gerontology Research Center and Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland

[2]JAMK University of Applied Sciences, School of Health and Social Studies, Jyväskylä, Finland

Corresponding author contact information:

Mailing address: Heidi Skantz, Gerontology Research Center and Faculty of Sport and Health Sciences, University of Jyväskylä, PO Box 35, 40014 Jyväskylä, Finland

Phone: +358 40 805 3721

E-mail: heidi.e.skantz@jyu.fi

Suggested running head: Free-Living Walking and Walking Capability

Associations between Accelerometer-Based Free-Living Walking and Self-Reported Walking Capability among Community-Dwelling Older People

ABSTRACT

Introduction: We examined whether accelerometer-based free-living walking differs between those reporting walking modifications or perceiving walking difficulty vs. those with no difficulty.

Methods: Community-dwelling 75-, 80- or 85-year-old people (N=479) wore accelerometers continuously for 3–7 days, and reported whether they perceived no difficulties, used walking modifications, or perceived difficulties walking 2km. Daily walking minutes, walking bouts, walking bout intensity and duration, and activity fragmentation were calculated from accelerometer recordings, and cut-points for increased risk for perceiving walking difficulties were calculated using ROC analysis.

Results: Our analyses showed that accumulating ≤83.1 daily walking minutes and walking bouts duration ≤47.8 seconds increased the likelihood of reporting walking modifications and difficulties. Accumulating walking bouts ≤99.4 per day, having walking bouts ≤0.119 g intensity, and ≥0.257 ASTP fragmented activity pattern were associated only with perceiving walking difficulties.

Conclusions: The findings suggest that older people's accelerometer-based free-living walking reflects their self-reported walking capability.

Keywords: aging, compensation, walking accumulation, mobility

INTRODUCTION

In the context of aging-related decline in individuals' competencies, walking can be maintained by increasing walking capacity (e.g., improving lower extremity function), lowering environmental demands (e.g., improving the accessibility of the environment), or modifying walking (e.g., using an aid or resting during walking) (Nahemow & Lawton, 1973; Skantz, Rantanen, Palmberg et al., 2020a; Skantz, Rantanen, Rantalainen et al., 2020b). Older people's outdoor walking consists mostly on running daily errands, such as going shopping (Davis et al., 2011; Tsai et al., 2016), and thus the maintenance of walking ability is essential in enabling independent living (Rantanen, 2013). In addition, walking is a commonly reported form of physical activity among older people (Lim & Taylor, 2005). Among the strategies for maintaining walking activity, those aimed at reducing task demands with walking modifications, such as lowering walking speed, using an aid, resting during walking, and reducing the frequency of walking longer distances (Mänty et al., 2007), are the most readily available to people facing functional decline. Based on the self-report measures, older people using walking modifications are able to continue walking longer distances (Skantz et al., 2020a) and postpone decline in life-space mobility compared to those with walking difficulties (Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2017; Skantz et al., 2020).

Walking modifications are typically used by older people who exhibit the first signs of functional decline but do not perceive themselves as having walking difficulties. Thus they form an intermediate group in their health and functional status between those with and those without walking difficulties (Fried, Bandeen-Roche, Chaves, & Johnson, 2000; Mänty et al., 2007). In addition to current functional status (Gitlin, Winter, & Stanley, 2017; Hoenig et al., 2006; Lang, Rieckmann, & Baltes, 2002; Skantz et al., 2020), the use of walking modifications is also related to features of an individual's living environment (Skantz et al., 2020). Older people with the first signs of functional decline who report barriers in their environment may be able to overcome them by modifying their walking activity and thus maintain their participation in outdoor activities (Skantz et al., 2020). As physical capacity further declines, environmental demands may exceed a person's capacity to negotiate the environment. This leads to considering such environmental features as mobility barriers and hindering the use of walking modifications (Skantz et al., 2020). This is the point when older people may start to experience walking difficulties and reduce their walking activity (Nahemow & Lawton, 1973; Weiss, Fried, & Bandeen-Roche, 2007).

While self-report measures of walking capability yield important knowledge about individuals' ability to walk in their own environment (what they **can** do) (Mänty et al., 2007), wearable accelerometers capture bouts of movement and non-movement in free-living conditions (what they **do** do). Thus, accelerometers can be used to gain information about free-living walking; the amount of walking (e.g. daily walking minutes, daily walking bouts, walking bout duration, and walking bout intensity) and about the patterns of daily walking activity (e.g. walking bout duration and activity fragmentation) (Palmberg et al., 2020; Schrack et al., 2018; Skotte, Korshøj, Kristiansen, Hanisch, & Holtermann, 2014). However, to the best of the present authors' knowledge, studies aimed at extracting walking bouts from free-living accelerometer data among older people are limited and the critical cut-points for increased risk for perceiving walking difficulties are undefined. In addition, studies on the associations of accelerometer-based free-living walking with self-reported walking modifications are lacking. Studying the associations between accelerometer-based free-living walking and self-reported walking capability will benefit researchers in interpretation of the future results, especially if it is not possible to gather information about walking by using both measures.

Based on previous findings, persons accumulating lower intensity in accelerometer-based physical activity and longer sedentary bouts more often report walking difficulties (Manns, Ezeugwu, Armijo-Olivo, Vallance, & Healy, 2015; Morie et al., 2010). Thus, it can be hypothesized that, accelerometer-based walking is associated with the use of walking modifications, as well as with walking difficulties. In addition, based on previous self-report data (Rantakokko et al., 2017; Skantz et al., 2020), it can be hypothesized that older people using walking modifications are able to maintain their free-living walking at close to the same level as those without walking difficulties. It has also been shown that as functional capacity declines, it becomes harder to maintain longer bouts of physically demanding activities, such as walking longer distances, and hence the activity patterns of daily life often become more fragmented (Palmberg et al., 2020; Schrack et al., 2018). We expect that persons who show a more fragmented activity pattern are either using walking modifications or perceive difficulties in walking 2-km distances, as higher activity fragmentation may indicate declining health (Schrack et al., 2018). However, the newest global physical activity guidelines suggests that physical activity at any intensity and duration, and reducing sedentary time throughout the day provides health benefits (Bull et al., 2020). Thus, breaking up sedentary time with short activity bouts throughout the day can be advantageous (Fanning et al., 2020).

The aim of this study was to determine optimal accelerometer-based free-living walking cut-points for an increased likelihood of self-reported walking difficulties. In addition, the aim was to investigate associations between the accelerometer-based free-living walking cut-points and self-reported walking capability, including walking difficulties and walking modifications.

METHODS

Study Design and Participants

This study is a part of the 'Active Ageing – resilience and external support as modifiers of the disablement outcome' (AGNES) observational cross-sectional cohort study. The study protocol (Rantanen et al., 2018) and non-respondent analyses (Portegijs, Karavirta, Saajanaho, Rantalainen, & Rantanen, 2019) have been reported previously. Briefly, AGNES is an observational study of three age cohorts (75, 80 and 85 years) living in the Jyväskylä area in Central Finland. A random sample of individuals based on age and residence in specific Jyväskylä postal code areas was drawn from Population Information System administered by the Finnish Population Register Centre (http://vrk.fi/en). The inclusion criteria for the study were living in the study area (Jyväskylä), being community-dwelling, willing to participate, and being able to communicate and provide an informed consent. After exclusions, a total of 1021 participants took part and were administered a face-to-face computer-assisted structured interview in their homes. Those willing to participate in the physical assessments in the research center (n = 910) were asked to wear an accelerometer for seven to ten days. An additional exclusion criterion for the accelerometer measurements was a known allergy to adhesive, since the accelerometer was directly taped onto the skin. In addition, participants who swam, bathed or took a sauna bath several times per week were excluded, as the accelerometers were not fully water-resistant. Finally, 496 participants agreed to wear the accelerometer. Based on the non-respondent analyses, those who did not participate in the accelerometer measurements had lower self-reported physical activity and lower walking speed than those wearing the accelerometers (Portegijs et al., 2019). The AGNES study was approved by ethical committee of the Central Finland Health Care District and the study protocol followed the principles of the Declaration of Helsinki.

Accelerometer Data

Free-living walking (daily walking minutes, daily walking bouts, walking bout duration, walking bout intensity, activity fragmentation) was assessed with a tri-axial accelerometer (range ±16 g, 13-bit analog-to-digital conversion, UKK RM42, UKK Terveyspalvelut Oy, Tampere, Finland) (Rantanen et al., 2018). The accelerometer was attached by a research assistant to the anterior aspect of the mid-thigh of the dominant leg with self-adhesive film during the home interview and participants were instructed to wear the accelerometer continuously for 7 to 10 days until the laboratory assessments. The dominant leg was defined primarily as the take-off leg, secondarily as the kicking leg, and thirdly as the leg on the side of the dominant hand (Karavirta et al., 2020). Although the self-adhesive film was waterproof, longer water-related activities such as swimming or taking a bath or sauna were not allowed while wearing the monitor. The data were verified visually to ensure that only days with complete 24-hour data without non-wear were included in the analysis. After excluding the data of 11 participants owing to either loss of monitor (n = 2), technical error (n = 1) or data availability for less than three full days (n = 8), acceptable accelerometer data were obtained for 485 participants. The accelerometer sampling rate was set at 100 samples per second and acceleration recorded in units of gravity (g). The mean amplitude deviation (MAD) of each 24-h epoch was calculated from the resultant acceleration ($resultant = \sqrt{X^2 + Y^2 + Z^2}$) in non-overlapping 5-second epochs (Vähä-Ypyä, Henri, Vasankari, Husu, Suni, & Sievänen, 2015; Vähä-Ypyä et al., 2015).

The previously defined method was modified and used to identify walking bouts from the free-living accelerometer data (Skotte et al., 2014). Continuous walking bouts of ≥ 20 sec in duration were identified based on the orientation angle of the thigh (an angle for postural estimation (APE) of < pi/4 to be eligible to be consideration as walking) (Vähä-Ypyä, H., Husu, Suni, Vasankari, & Sievänen, 2018), and the signal intensity (MAD of between 0.035 g and 1.2 g, results of the laboratory experimentation). Thereafter, *daily walking bouts* (bouts/d), *walking bout duration* (sec) and *walking bout intensity* (g) were calculated. *Mean daily walking minutes* (min/d) were calculated by multiplying walking bouts by walking bout duration. *Activity fragmentation* was assessed as the Active-to-Sedentary Transition Probability (ASTP), i.e., the probability of transitioning from an active to a sedentary state (Schrack et al., 2018). The ASTP was calculated by dividing the number of activity bouts by the mean sum of active daily minutes (at least light activity, with a MAD value of at least 16.7 mg) (Palmberg et al., 2020). A higher ASTP represents a more fragmented activity pattern. Daily walking minutes, daily walking bouts, walking bout duration, walking bout intensity, and activity fragmentation were used as continuous variables in the analyses.

Questionnaire Data

Self-reported walking capability was evaluated based on self-reported walking difficulties and walking modifications. First, participants were asked if they perceived difficulties in walking 2 kilometers (km) with a standardized question: "*Do you have difficulty walking 2 kilometers?"* (Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2016). The response alternatives were 1) able to manage without difficulty, 2) able to manage with some difficulty, 3) able to manage with a great deal of difficulty, 4) able to manage only with help of another person, and 5) unable to manage even with help. Second, to identify participants using walking modifications, those who reported being able to walk 2 km without difficulties were asked an additional question: "*Have you noticed any of the following changes when walking 2 km due to your health or physical functioning*?". The walking modifications were: walking slower, resting during walking, using an aid, reduced frequency of walking, and having given up walking distances of 2 km. Participants were asked to report all the walking modifications that they used ("yes" or "no"). For the analyses, participants were categorized into groups of *self-reported walking capability* as follows: 1) *no difficulties* (reporting neither difficulty nor modifications), 2) *walking modifications* (reporting no difficulties and ≥ 1 modification) and 3) *walking difficulties* (reporting at least some difficulty).

Age and sex were drawn from national population register. Years of education, number of chronic conditions, depressive symptoms and lower extremity function were assessed during the at-home interview and examination. *Years of education*, used as an indicator of socioeconomic status, was self-reported. *Number of chronic conditions* was calculated as the sum of individual chronic conditions selected from a list of specific physician-diagnosed chronic conditions followed by an open-ended question on any other chronic conditions the participant might have (Rantanen et al., 2018). *Depressive symptoms* were assessed with the Center for Epidemiologic Studies Depression Scale, CES-D (range 0–60, with higher scores indicating more depressive symptoms) (Radloff, 1977). *Lower extremity function* was assessed with the Short Physical Performance Battery (SPPB, range 0-12, with higher scores indicating better lower extremity function) and included balance, walking speed and chair stands (Guralnik et al., 1994; Rantanen et al., 2018).

Statistical Analyses

Descriptive statistics by self-reported walking capability were reported in percentages for categorical variables and means with standard deviations (SD) for continuous variables, and differences between groups were tested with chi-square tests (χ^2) or one-way analysis of variance (ANOVA). As preliminary analyses mostly showed differences in free-living walking between participants with no difficulties and participants with walking difficulties, Receiver Operating Characteristics (ROC) analysis (Akobeng, 2007) was performed to estimate optimal accelerometer-based free-living walking (daily walking minutes, daily walking bouts, walking bout duration, walking bout intensity, activity fragmentation) cut-points for predicting perceived walking difficulties. The advantage of Receiver Operating Characteristics (ROC) analysis is that it is free from parametric assumptions (Lasko, Bhagwat, Zou, & Ohno-Machado, 2005). In these analyses, participants with no difficulties and those with walking modifications were merged into the same reference group (n = 341). The cut-points that best balanced the high sensitivity and high specificity of the test were calculated by finding the minimal value by using formula $(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2$. The suitability of the test was evaluated by estimating the area under the curve (AUC). This value serves as a single measure that indicates the accuracy of the test: 0.5–0.7 = low accuracy, 0.7–0.9 = moderate accuracy, > 0.9 = high accuracy (Akobeng, 2007).

After calculating the optimal cut-points, the associations of free-living walking with self-reported walking capability were assessed by using multinomial logistic regression analysis. Multinomial logistic regression analysis was used because the outcome variable was a nominal scale variable. Those with no difficulties were used as a reference group in the analyses. The models were first unadjusted and then adjusted for age, sex and years of education. Age and sex were available for all participants with adequate accelerometer data; however, for six participants information on self-reported walking capability was missing, and thus 479 participants with adequate accelerometer data were included into this study. A further four participants had missing information for years of education and thus these participants were not included in the fully adjusted models. IBM SPSS version 24 for Windows (IBM Corp., Armonk, NY) was used for statistical analyses. The results were regarded as statistically significant if the 95 % confidence intervals did not include 1 or when the p-value was < 0.05.

RESULTS

Participant characteristics by self-reported walking capability are presented in Table 1. Comparison by self-reported walking capability revealed that those with walking difficulties ($n = 138$) had the poorest CES-D and SPPB scores, while those with no difficulties ($n = 261$) reported the least depressive symptoms and best lower extremity function (Table 1). Based on the post hoc comparisons, the older people with walking modifications ($n = 80$) did not differ from those without walking difficulties in age ($p = 0.347$), years of education ($p = 0.319$), depressive symptoms ($p = 0.166$) or number of chronic conditions ($p = 0.455$). Instead, participants with walking modifications formed a middle group in lower extremity function between those with no difficulties and those with walking difficulties ($p < 0.001$ for both) and had less chronic conditions than those with walking difficulties ($p < 0.001$).

Across all participants, the mean number of daily walking minutes was 101.9 (SD 42.2) and the mean number of daily walking bouts 114.1 (SD 41.2). Mean walking bout intensity was 0.12 (SD 0.02) g, mean bout duration 53.7 (SD 13.5) seconds, and mean activity fragmentation 0.24 ASTP (SD 0.06). Those without walking difficulties accumulated the highest number of daily walking minutes (115.0 min, SD 37.9) and walking bouts (120.2, SD 38.1). Their walking bouts were also the longest (58.5 sec, SD 14.0), and showed the highest average intensity (0.23 g, SD 0.05) (Table 1). In addition, their activity was the least fragmented (0.23 ASTP, SD 0.05). Participants reporting walking modifications had a similar mean number (120.7, SD 45.0, $p = 1.000$) and intensity (0.12 g, SD 0.02, $p = 0.751$) of daily walking bouts and a similar activity fragmentation pattern (0.24 ASTP, SD 0.06, $p = 0.594$) as those without walking difficulties. However, participants reporting walking modifications accumulated fewer daily walking minutes (102.4 min, SD 42.9, $p = 0.035$) and had shorter walking bouts (50.9 sec, SD 9.7, $p < 0.001$) than those without walking difficulties. Participants with walking difficulties showed the poorest values in all the free-living walking variables.

The associations between free-living walking cut-points and self-reported walking capability

The free-living walking cut-points for increased risk for reporting walking difficulties were established by using ROC curve analyses (Table 2). Daily walking minutes (cut-point 83.1 min, AUC 0.745), walking bout duration (cut-point 47.8 sec, AUC 0.756), and activity fragmentation (cut-point 0.257 ASTP, AUC 0.715) showed moderate accuracy, while the number of daily walking bouts (cut-point 99.4 bouts) and walking bout intensity (cut-point 0.119 g) showed low accuracy (AUC < 0.7) in discriminating between older people with walking difficulties and those without difficulties. Multinomial logistic regression analyses revealed that, adjusting the models for age, sex and years of education did no change the associations between free-living walking and self-reported walking capability, and thus we present only adjusted models (Table 3). In the analyses, participants walking less than 83.1 minutes daily had over two-fold greater odds for using walking modifications and 5.5-fold odds for perceiving walking difficulties than perceiving no difficulties. Similarly, participants accumulating walking bouts shorter than 47.8 seconds had over two-fold greater odds for using walking modifications and over 6-fold greater odds for perceiving walking difficulties than perceiving no difficulties. Accumulating walking bouts equal to or less than 99.4 per day, having walking bouts equal to or lower than 0.119 g intensity, and having a more fragmented activity pattern were associated with perceiving walking difficulties but not with the use of walking modifications.

DISCUSSION

To the authors' best knowledge, this is the first study to establish accelerometer-based free-living walking cut-points for predicting increased risk of perceiving walking difficulties and to investigate the associations of these cut-points with self-reported walking capability. The present findings showed that differences in daily walking activity and walking patterns were, as expected, related to self-reported walking capability. We observed that accumulating 83 or fewer daily walking minutes and walking bouts of 48 seconds or shorter duration were associated with the use of walking modifications or perceiving walking difficulties.

In this study, we observed that people with shorter walking bouts were more likely to report walking modifications than no walking difficulties. This finding is reasonable, since walking modifications include taking rest breaks during longer walks perceived as tiring, meaning that older people with the first signs of functional decline start dividing their walking into shorter bouts to avoid exhaustion or to avoid pain (Brawley, Rejeski, & King, 2003). Moreover, as shown in previous studies, this strategy enables them to maintain their self-reported outdoor mobility on the same level as before (Rantakokko et al., 2017; Skantz et al., 2020). We also observed slightly fewer daily walking minutes among those using walking modifications than those without walking difficulties. This finding was expected, since older people using walking modifications are already experiencing the first signs of declining physical capacity (Fried et al., 2000; Mänty et al., 2007). This finding is also consistent with the results of our previous study in which we observed a slightly lower life-space mobility score among older people using walking modifications than those with no difficulties (Skantz et al., 2020). However, the life-space mobility measurement includes other ways of moving besides walking, such as using a car or public transport (Baker, Bodner, & Allman, 2003), and thus older people with poorer physical capacity may be able to achieve higher life-space mobility scores if they are able to use car or public transport.

In line with previous studies (Manns et al., 2015; Morie et al., 2010; Schrack et al., 2018), we noticed that the present sample of older people with walking difficulties accumulated 36 fewer daily walking minutes than those without walking difficulties, who averaged around almost two hours walking daily. Moreover, the daily walking activity of older people with walking difficulties may consist mainly of indoor walking, as their walking bouts were of shorter duration and lower intensity and their activity was more fragmented compared to those without walking difficulties. In addition, the longer walking bouts among people without walking difficulties suggest that they may run errands located also further away from home on foot (Davis et al., 2011; Tsai et al., 2016), or they may go for walks to exercise (Lim & Taylor, 2005). However, walking outdoors, with the help of others or with a walking aid, would be beneficial for older people perceiving walking difficulties, as previous research has shown that older people are more physically active on days when they go outdoors from their homes (Portegijs, Tsai, Rantanen, & Rantakokko, 2015). In addition, older people with walking difficulties would gain health benefits by breaking up sedentary time even with short activity bouts throughout the day (Bull et al., 2020; Fanning et al., 2020). Differences in daily walking activity and activity patterns were also observed between older people with walking modifications and those with walking difficulties. This finding supports previous suggestions that older people using walking modifications form an intermediate group between older people with and those without walking difficulties (Fried et al., 2000; Mänty et al., 2007). Thus, it is important to include the questions of the use of walking modifications in studies investigating older people's self-reported walking capability.

In previous studies, physical capacity and health are shown to be associated with self-reported walking capability (Ganesh, Fried, Taylor, Pieper, & Hoenig, 2011; Hoenig et al., 2006). However, including lower extremity function and other health characteristics into our models, would have potentially led to over-adjustment, as they may be factors on the pathway rather than confounders. It is possible that, poor physical capacity increases the risk for low levels of physical activity (Portegijs, Rantakokko, Mikkola, Viljanen, & Rantanen, 2014) and perceiving walking difficulties (Ganesh et al., 2011). In turn, low levels of physical activity, together with aging-related changes, declines physical capacity (Fielding et al., 2017). The use of walking modifications may, by slowing or even halting this chain of events, help older people to continue walking despite poor physical capacity (Skantz et al., 2020). However, studying this chain of events requires longitudinal data.

The strengths of this study include the accelerometer-based assessment of the free-living walking of a relatively large population-based sample of community-dwelling older people. Using accelerometer data enabled us to study the associations of older people's free-living daily walking activity with perceived walking modifications, whereas previous studies have been limited to self-reported data or have investigated the associations of accelerometer-based walking with perceived walking difficulties without considering the use of walking modifications (Manns et al., 2015; Morie et al., 2010; Skantz et al., 2020). The present self-reported data were gathered during face-to-face structured interviews, and therefore missing values were few. Moreover, we used a self-reported walking modifications measure that has been shown to be a validated and reliable indicator of preclinical disability (Mänty et al., 2007).

The study also has its limitations. First, this study reported cross-sectional findings and thus causality cannot be inferred. Therefore, longitudinal studies are needed to ascertain whether accelerometer-based free-living walking cut-points predicts self-reported walking capability over time. Second, our study population comprised relatively well-functioning older people, as those who wore accelerometers, and thus participated in this study, reported higher levels of physical activity than those who did not wear accelerometers (Portegijs et al., 2019). Thus, the study should be repeated with the more vulnerable older people to determine whether they exhibit similar associations. Third, the participants using walking modifications can be expected to be heterogeneous in their level of physical functioning. However, since data on walking modifications were only collected from those who were able to walk 2 km without difficulties, we were unable to categorize walking modifications into adaptive and maladaptive types (Skantz et al., 2020). Despite this limitation, studying walking modifications among those without walking difficulties was informative on how walking activity can be sustained among those who are at increased risk for future walking difficulties. Finally, only ≥ 20 seconds long walking bouts were identified and used in our analyses because we wanted to make sure that we will capture only actual walking bouts excluding light moving or standing still. However, using this cut-point may under-estimate the amount of daily walking minutes especially among those with walking difficulties. In addition, the original method for identifying types of physical activity (Skotte et al., 2014) was modified, as we have found from visual inspection that distinguishing stair walking from walking on the flat lead to misclassification. Thus, our analyses include stair walking. Skotte et al. (2014) also reported challenges in identifying stair walking. However, in future studies, it would be interesting to differentiate stair walking from walking on the flat, as stair walking presents a major challenge for muscle strength in older people (Tikkanen et al., 2016).

CONCLUSIONS

This study showed that older people's self-reported walking capability is partly determined by their daily walking pattern, especially by the accumulation of daily walking minutes and duration of walking bouts. These findings, together with previous findings, suggest that older people evaluate walking capability based on their free-living walking, physical capacity, and current living environment. In addition, we observed that self-reported walking capability gives a realistic picture of older peoples' walking activity in their everyday life.

ACKNOWLEDGEMENTS

We thank the whole AGNES research team, especially Eeva-Maija Palonen, Markku Kauppinen, Niina Kajan and, all research assistants for their work in the data collection and analyses and all participants of the AGNES study for their time and effort. The Gerontology Research Center (GEREC) is a joint effort between the University of Jyväskylä and the University of Tampere, Finland. Author contributions were: Concept and design (HS, TiR, LK, MR, LP, EP, TaR), acquisition of data (HS, TiR, LK, MR, LP, EP, TaR), analysis and/or interpretation of data (HS, TiR, LK, MR, LP, EP, TaR), drafting the article (HS), and critical revision of the article (TiR, LK, MR, LP, EP, TaR). All authors approved the final manuscript.

CONFLICT OF INTEREST

MR serves on the Journal of Aging and Physical Activity editorial board. Otherwise, the authors declare no conflicts of interest.

FUNDING

This work was supported by the European Research Council (grant number 693045 to TaR), the Academy of Finland (grant number 310526 to TaR and grant numbers 321336 and 328818 to TiR), the Finnish Ministry of Education and Culture (to MR, TaR and EP), and the University of Jyväskylä. The financial sponsors were not involved in the design, implementation, analyses or reporting of the results. In addition, the content of this manuscript does not reflect the official opinion of the European Union. Responsibility for the information and views expressed in the manuscript lies entirely with the authors.

References

Akobeng, A. K. (2007). Understanding diagnostic tests 3: Receiver operating characteristic curves. *Acta Paediatrica, 96*(5), 644-647.

Baker, P. S., Bodner, E. V., & Allman, R. M. (2003). Measuring life-space mobility in community-dwelling older adults. *Journal of the American Geriatrics Society, 51*(11), 1610-1614. doi:10.1046/j.1532-5415.2003.51512.x

Brawley, L. R., Rejeski, W. J., & King, A. C. (2003). Promoting physical activity for older adults: The challenges for changing behavior. *American Journal of Preventive Medicine, 25*(3), 172-183.

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., . . . Chou, R. (2020). World health organization 2020 guidelines on physical activity and sedentary behaviour.

Davis, M. G., Fox, K. R., Hillsdon, M., Coulson, J. C., Sharp, D. J., Stathi, A., & Thompson, J. L. (2011). Getting out and about in older adults: The nature of daily trips and their association with objectively assessed physical activity. *International Journal of Behavioral Nutrition and Physical Activity, 8*(1), 116.

Fanning, J., Rejeski, W. J., Chen, S., Guralnik, J., Pahor, M., & Miller, M. E. (2020). Relationships between profiles of physical activity and major mobility disability in the LIFE study. *Journal of the American Geriatrics Society,*

Fielding, R. A., Guralnik, J. M., King, A. C., Pahor, M., McDermott, M. M., Tudor-Locke, C., . . . Axtell, R. S. (2017). Dose of physical activity, physical functioning and disability risk in mobility-limited older adults: Results from the LIFE study randomized trial. *PLoS One*, *12*(8), e0182155.

Fried, L. P., Bandeen-Roche, K., Chaves, P. H., & Johnson, B. A. (2000). Preclinical mobility disability predicts incident mobility disability in older women. *Journals of Gerontology-Biological Sciences and Medical Sciences*, *55*(1), M43.

Ganesh, S. P., Fried, L. P., Taylor, D. H., Pieper, C. F., & Hoenig, H. M. (2011). Lower extremity physical performance, self-reported mobility difficulty, and use of compensatory strategies for mobility by elderly women. *Archives of Physical Medicine and Rehabilitation*, *92*(2), 228-235.

Gitlin, L. N., Winter, L., & Stanley, I. H. (2017). Compensatory strategies: Prevalence of use and relationship to physical function and well-being. *Journal of Applied Gerontology, 36*(6), 647-666. doi:10.1177/0733464815581479

Guralnik, J. M., Simonsick, E. M., Ferrucci, L., Glynn, R. J., Berkman, L. F., Blazer, D. G., . . . Wallace, R. B. (1994). A short physical performance battery assessing lower extremity function: Association with self-reported disability and prediction of mortality and nursing home admission. *Journal of Gerontology, 49*(2), M85-M94.

Hoenig, H., Ganesh, S. P., Taylor Jr, D. H., Pieper, C., Guralnik, J., & Fried, L. P. (2006). Lower extremity physical performance and use of compensatory strategies for mobility. *Journal of the American Geriatrics Society, 54*(2), 262-269. doi:10.1111/j.1532-5415.2005.00588.x

Karavirta, L., Rantalainen, T., Skantz, H., Lisko, I., Portegijs, E., & Rantanen, T. (2020). Individual scaling of accelerometry to preferred walking speed in the assessment of physical activity in older adults. *The Journals of Gerontology: Series A,*

Lang, F. R., Rieckmann, N., & Baltes, M. M. (2002). Adapting to aging losses: Do resources facilitate strategies of selection, compensation, and optimization in everyday functioning? *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 57*(6), P501-P509. doi:10.1093/geronb/57.6.p501

Lasko, T. A., Bhagwat, J. G., Zou, K. H., & Ohno-Machado, L. (2005). The use of receiver operating characteristic curves in biomedical informatics. *Journal of Biomedical Informatics, 38*(5), 404-415. doi:https://doi.org/10.1016/j.jbi.2005.02.008

Lim, K., & Taylor, L. (2005). Factors associated with physical activity among older people—a population-based study. *Preventive Medicine*, *40*(1), 33-40.

Manns, P., Ezeugwu, V., Armijo-Olivo, S., Vallance, J., & Healy, G. N. (2015). Accelerometer-derived pattern of sedentary and physical activity time in persons with mobility disability: National health and nutrition examination survey 2003 to 2006. *Journal of the American Geriatrics Society, 63*(7), 1314-1323.

Mänty, M., Heinonen, A., Leinonen, R., Törmäkangas, T., Sakari-Rantala, R., Hirvensalo, M., . . . Rantanen, T. (2007). Construct and predictive validity of a self-reported measure of preclinical mobility limitation. *Archives of Physical Medicine and Rehabilitation, 88*(9), 1108-1113. doi:10.1016/j.apmr.2007.06.016

Morie, M., Reid, K. F., Miciek, R., Lajevardi, N., Choong, K., Krasnoff, J. B., . . . LeBrasseur, N. K. (2010). Habitual physical activity levels are associated with performance in measures of physical function and mobility in older men. *Journal of the American Geriatrics Society, 58*(9), 1727-1733.

Nahemow, L., & Lawton, M. P. (1973). Toward an ecological theory of adaptation and aging. *Environmental Design Research, 1*, 24-32.

Palmberg, L., Rantalainen, T., Rantakokko, M., Karavirta, L., Siltanen, S., Skantz, H., . . . Rantanen, T. (2020). The associations of activity fragmentation with physical and mental fatigability among community-dwelling 75-, 80- and 85-year-old people. *The Journals of Gerontology: Series A,* , glaa166. doi:10.1093/gerona/glaa166

Portegijs, E., Karavirta, L., Saajanaho, M., Rantalainen, T., & Rantanen, T. (2019). Assessing physical performance and physical activity in large population-based aging studies: Home-based assessments or visits to the research center? *BMC Public Health, 19*(1), 1570.

Portegijs, E., Rantakokko, M., Mikkola, T. M., Viljanen, A., & Rantanen, T. (2014). Association between physical performance and sense of autonomy in outdoor activities and life-space mobility in community-dwelling older people. *Journal of the American Geriatrics Society, 62*(4), 615-621. doi:10.1111/jgs.12763

Portegijs, E., Tsai, L., Rantanen, T., & Rantakokko, M. (2015). Moving through life-space areas and objectively measured physical activity of older people. *PloS One, 10*(8), e0135308.

Radloff, L. S. (1977). The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement, 1*(3), 385-401. doi:10.1177/014662167700100306

Rantakokko, M., Portegijs, E., Viljanen, A., Iwarsson, S., & Rantanen, T. (2016). Mobility modification alleviates environmental influence on incident mobility difficulty among community-dwelling older people: A two-year follow-up study. *PloS One, 11*(4), e0154396. doi:10.1371/journal.pone.0154396

Rantakokko, M., Portegijs, E., Viljanen, A., Iwarsson, S., & Rantanen, T. (2017). Task modifications in walking postpone decline in life-space mobility among community-dwelling older people: A 2-year follow-up study. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences,* , glw348. doi:10.1093/gerona/glw348

Rantanen, T. (2013). Promoting mobility in older people. *Journal of Preventive Medicine and Public Health, 46*(Suppl 1), S50.

Rantanen, T., Saajanaho, M., Karavirta, L., Siltanen, S., Rantakokko, M., Viljanen, A., . . . Lisko, I. (2018). Active aging–resilience and external support as modifiers of the disablement outcome: AGNES cohort study protocol. *BMC Public Health, 18*(1), 565.

Schrack, J. A., Kuo, P., Wanigatunga, A. A., Di, J., Simonsick, E. M., Spira, A. P., . . . Zipunnikov, V. (2018). Active-to-sedentary behavior transitions, fatigability, and physical functioning in older adults. *The Journals of Gerontology: Series A*, *74*(4), 560-567.

Skantz, H., Rantanen, T., Palmberg, L., Rantalainen, T., Aartolahti, E., Portegijs, E., . . . Rantakokko, M. (2020). Outdoor mobility and use of adaptive or maladaptive walking modifications among older people. *The Journals of Gerontology: Series A, 75*(4), 806-812. doi:10.1093/gerona/glz172

Skantz, H., Rantanen, T., Rantalainen, T., Keskinen, K. E., Palmberg, L., Portegijs, E., . . . Rantakokko, M. (2020). Associations between perceived outdoor environment and walking modifications in community-dwelling older people: A two-year follow-up study. *Journal of Aging and Health,* , 0898264320944289. doi:10.1177/0898264320944289

Skotte, J., Korshøj, M., Kristiansen, J., Hanisch, C., & Holtermann, A. (2014). Detection of physical activity types using triaxial accelerometers. *Journal of Physical Activity and Health*, *11*(1), 76-84.

Tikkanen, O., Sipilä, S., Kuula, A., Pesola, A., Haakana, P., & Finni, T. (2016). Muscle activity during daily life in the older people. *Aging Clinical and Experimental Research, 28*(4), 713-720.

Tsai, L., Rantakokko, M., Viljanen, A., Saajanaho, M., Eronen, J., Rantanen, T., & Portegijs, E. (2016). Associations between reasons to go outdoors and objectively-measured walking activity in various life-space areas among older people. *Journal of Aging and Physical Activity, 24*(1), 85-91.

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*(3), 1092-1102.

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*(1), 64-70.

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*(8), e0134813.

Weiss, C. O., Fried, L. P., & Bandeen-Roche, K. (2007). Exploring the hierarchy of mobility performance in high-functioning older women. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *62*(2), 167-173.

Table 1. Baseline Characteristics by Self-Reported Walking Capability (N = 479).

Characteristics	No difficulties (n = 261) Mean (SD)	Modifications (n = 80) Mean (SD)	Difficulties (n = 138) Mean (SD)	P-value
Age (y)	77.7 (3.1)	78.4 (3.3)	79.6 (3.7)	**<.001** [a]
Education (y)	12.2 (4.2)	11.3 (4.6)	10.8 (4.1)	**0.006** [a]
No. of chronic conditions	2.7 (1.7)	3.0 (2.0)	4.6 (2.1)	**<.001** [a]
CES-D	6.5 (6.1)	8.1 (6.8)	10.3 (7.0)	**<.001** [a]
SPPB	11.0 (1.3)	10.2 (1.6)	9.0 (2.4)	**<.001** [a]
Female, %	54.8	56.3	71.0	**0.003** [b]
Daily walking minutes	115.0 (37.9)	102.4 (42.9)	76.7 (38.2)	**<.001** [a]
Number of walking bouts	120.2 (38.1)	120.70 (45.0)	98.56 (40.7)	**<.001** [a]
Average walking bout intensity, g	0.13 (0.02)	0.12 (0.02)	0.12 (0.03)	**<.001** [a]
Average walking bout duration, sec	58.5 (14.0)	50.9 (9.7)	46.3 (10.7)	**<.001** [a]
Activity fragmentation	0.23 (0.05)	0.24 (0.06)	0.28 (0.07)	**<.001** [a]

Note: CES–D = Center for Epidemiologic Studies Depression Scale, SPPB = Short Physical Performance Battery. [a]: tested with one–way analysis of variance, [b]: tested with chi square test. Statistically significant p-values are bolded.

Table 2. Sensitivity and Specificity of Accelerometer-Based Daily Walking Minutes, Daily Walking Bouts, Walking Bout Intensity, Walking Bout Duration, and Activity Fragmentation in Identifying Walking Difficulties.

	Cut-point	Sensitivity, %	Specificity, %	Area under curve (95 % CI)
Daily walking minutes	83.1	63	74	0.745 (0.696–0.794)
Daily walking bouts	99.4	56	66	0.646 (0.590–0.702)
Walking bout intensity, g	0.119	62	60	0.641 (0.584–0.697)
Walking bout duration, sec	47.8	67	73	0.756 (0.702–0.801)
Fragmentation*	0.257	58	73	0.715 (0.663–0.766)

Note: Values equal to or below the cut-point are related to perceived walking difficulties. Walking difficulties were defined as reporting at least minor difficulties in walking 2-km distances and compared to reporting no walking difficulties (including use of walking modifications).

*Values equal or over the cut-point are related to perceived walking difficulties.

Table 3. Associations of Free-Living Walking with Self-Reported Walking Capability in Community-Dwelling Older People. Odds are Reported for Those with Walking Modifications and Walking Difficulties vs. Those with No Walking Difficulties (Reference).

	Crude				Model 1			
Free-living walking	Walking modifications (n = 80)		Walking difficulties (n = 138)		Walking modifications (n = 78)		Walking difficulties (n = 136)	
	OR (95 % CI)	P-value	OR (95 % CI)	P-value	OR (95 % CI)	P-value	OR (95 % CI)	P-value
Daily walking minutes ≤ 83.1 min vs. > 83.1 min	**2.6 (1.5–4.5)**	**<0.001**	**6.4 (4.1–10.1)**	**<0.001**	**2.6 (1.5–4.5)**	**0.001**	**5.5 (3.4–8.8)**	**<0.001**
Number of walking bouts ≤ 99.4 vs. > 99.4	1.0 (0.6–1.8)	0.894	**2.7 (1.7–4.0)**	**<0.001**	1.0 (0.6–1.7)	0.958	**2.3 (1.5–3.6)**	**<0.001**
Walking bout intensity ≤ 0.119 g vs. > 0.119 g	1.4 (0.8–2.3)	0.185	**2.4 (1.6–3.7)**	**<0.001**	1.3 (0.8–2.2)	0.303	**1.9 (1.2–3.0)**	**0.005**
Walking bout duration ≤ 47.8 sec vs. > 47.8 sec	**2.3 (1.4–3.9)**	**0.002**	**6.8 (4.3–10.7)**	**<0.001**	**2.3 (1.3–3.9)**	**0.003**	**6.7 (4.2–10.9)**	**<0.001**
Activity fragmentation ≥ 0.257 vs. < 0.257	1.2 (0.7–2.0)	0.532	**3.8 (2.5–5.9)**	**<0.001**	1.1 (0.7–2.0)	0.642	**3.3 (2.1–5.1)**	**<0.001**

Note: Multinomial logistic regression analyses. Reference category: no difficulties, n=261. Model 1: Adjusted for age, sex and years of educations.

OR = Odds Ratio; CI = Confidence Interval. Statistically significant values are bolded.