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# Robustness of In-Laboratory and Daily-Life Gait Speed Measures over One Year in High Functioning 61- to 70-Year-Old Adults

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**Keywords**
Accelerometry · Walking speed · Motor activity · Longitudinal studies

**Abstract**
***Introduction:*** Gait speed is a simple and safe measure with strong predictive value for negative health outcomes in clinical practice, yet in-laboratory gait speed seems not representative for daily-life gait speed. This study aimed to investigate the interrelation between and robustness of in-laboratory and daily-life gait speed measures over 12 months in 61- to 70-year-old adults. ***Methods:*** Gait speed was assessed in laboratory through standardized stopwatch tests and in daily life by 7 days of trunk accelerometry in the PreventIT cohort, at baseline, and after 6 and 12 months. The interrelation was investigated using Pearson's correlations between gait speed measures at each time point. For robustness, changes over time and variance components were assessed by ANOVA and measurement agreement over time by Bland-Altman analyses. ***Results:*** Included were 189 participants (median age 67 years [interquartile range: 64–68], 52.2% females). In-laboratory and daily-life gait speed measures showed low correlations (Pearson's $r = 0.045–0.455$) at each time point. Moreover, both in-laboratory and daily-life gait speed measures appeared robust over time, with comparable and smaller within-subject than between-subject variance (range 0.001–0.095 m/s and 0.032–0.397 m/s, respec-

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tively) and minimal differences between measurements over time (Bland-Altman) with wide limits of agreement (standard deviation of mean difference range: 0.12–0.34 m/s). ***Discussion/Conclusion:*** In-laboratory and daily-life gait speed measures show robust assessments of gait speed over 12 months and are distinct constructs in this population of high-functioning adults. This suggests that (a combination of) both measures may have added value in predicting health outcomes.



## Introduction

Gait speed measured under standardized conditions, that is, by use of specific protocols and speed instructions (in-laboratory gait speed), is known to be associated with disability, comorbidity, and mortality [1, 2]. Slowing of in-laboratory gait speed over time is known to predict mortality as well as incident dementia [3, 4]. This contributes to the implementation of the assessment of gait speed as a simple, safe, and easy predictive measure to assess in clinical practice [5, 6].

However, cross-sectional studies showed that in-laboratory assessment of gait speed is only weakly related to daily-life gait speed in community-dwelling adults [7, 8]. While in-laboratory gait speed likely represents someone's best performance (known as the Hawthorne effect [9]), daily-life gait speed as assessed with inertial sensors characterizes a range of daily physical activities under a variety of circumstances and purposes [10, 11]. Therefore, these 2 measures are suggested to represent 2 different constructs, representing related but separate characteristics of someone's performance. However, it remains unclear how these constructs, as well as their mutual relationship, develop over time. Gaining insights into this temporal relation will guide us in the future implementation of the combined use of in-laboratory and daily-life gait speed, with a special interest for the possible added value of daily-life gait speed measures in clinical practice.

The aim of this study was to explore the interrelation of gait speed measures assessed in laboratory (i.e., as 4-m usual speed, 7-m usual speed, and 7-m fast speed) and in daily life (i.e., number of epochs, percentiles, and peaks) over time in high-functioning adults aged 61 to 70 years and to investigate their robustness over time with respect to a lifestyle intervention (Lifestyle-integrated Functional Exercise, LiFE). We compared measurements at baseline, and after 6- and 12-month follow-ups as part of a secondary analysis of the PreventIT study. We hypothesized that both in-laboratory and daily-life gait speed measures, as well as their mutual relation, will show consistent results over time, with low within-subject and between-subject variance components, more so in the in-laboratory than in the daily-life gait speed measures.

## Methods

*Study Design*

We used longitudinal data of the 189 community-dwelling adults aged 61 to 70 years who participated in the PreventIT EU project (H2020 – grant agreement No. 689238). Participants were recruited via invitation letters, which were sent to a random sample of individuals born between January 01, 1947 and December 31, 1956, drawn from the respective local population registries. Initial screening consisted of a telephone interview assessing the following eligibility criteria: aged 61–70 years, retired or working part-time, community dwelling (living independently), able to read a newspaper or text on a smartphone, speak Norwegian/German/Dutch, able to walk 500 m without a walking aid, and available for home visits during the following 6 weeks. Those already participating in an organized exercise class (>1/week), undertaking moderate-intensity physical activity (≥150 min/week in the previous 3 months), or with long-term travel plans (>2 months) within the next 6 months were excluded. A Web-based risk-screening tool [12] was used to describe participants' risk of long-term accelerated functional decline. Medical screening ensured that exercise was not contraindicated. The final exclusion criteria included cognitive impairment (Montreal Cognitive Assessment [MoCA] ≤24 [13] or depression [defined as acute depression by a health professional at assessment in Trondheim and Amsterdam or as major depression with CES-D [14] cutoff of >24 points in Stuttgart]). This 3-year project adapted the LiFE program [15] as an intervention for adults targeting balance, muscle strength, and physical activity delivered either via a smartphone application (enhanced LiFE) or by use of paper manuals (adapted LiFE). Participants were randomized into 3 groups: an enhanced LiFE, adapted LiFE, or control group who received education material regarding the World Health Organization recommendations of physical activity. In-laboratory and daily-life gait speed measures were assessed at baseline, and after 6- and 12-month follow-ups. Detailed information on recruitment, eligibility, and randomization is published elsewhere [16]. The present study was part of a secondary analysis of the PrevenIT study [16, 17].

*Data Collection*

Characteristics

The following demographic and descriptive information was collected at baseline: age, sex, weight, height, number of morbidities, number of medications, history of falls in the past 6 months, experiencing any pain during rest or walking, and units of alcohol consumption per week. Body weight was assessed in kilograms, and height was assessed in centimeter. BMI (kg/m$^2$) was calculated using both weight and height. The number of morbidities was assessed by the self-reported presence or a history of the following illnesses including diabetes mellitus, hypertension, orthostatic hypotension, ischemic heart diseases, heart failure, atrial fibrillation, cardiac dysrhythmias or arrest, valvular disease, peripheral artery

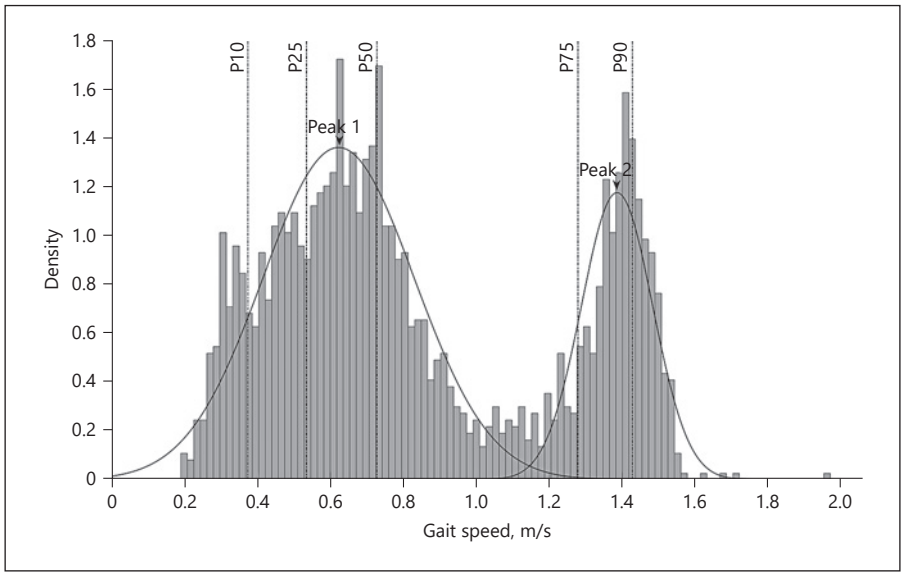


**Fig. 1.** Example of an individual's distribution of daily-life gait speed. Note: Gray bars represent the observations of daily-life gait speed expressed as the density over all 10-s gait epochs; the solid black line represents the optimal bimodal fit with 2 peak values in daily-life gait speed; the vertical dotted black lines represent the different percentiles of daily-life gait speed. P, percentile.

disease, cerebrovascular accident or stroke, transient ischemic attack, arthrosis, rheumatoid arthritis, other arthropathies or joint disorders, dorsopathies, osteoporosis, fractures, cancer, chronic obstructive pulmonary disease, asthma, Parkinson's disease, or epilepsy. The number of medications was reported, not taking vitamins and other supplements into account. The use of pain medication was documented separately.

Standardized In-Laboratory Gait Speed Assessments

In-laboratory gait speed was assessed using 3 different and commonly used standardized tests: 4-m usual pace walk test, 7-m usual pace walk test, and the 7-m fast pace walk test. For the 4-m usual pace, the participants were instructed to walk at their usual pace as if "they were walking down the street towards the store." This test was conducted with a static start. For the 7-m usual and fast pace walks, the participants were instructed to walk at their usual or fast pace from a dynamic start, that is, the walking distance covered 9 m of which the middle 7 were used to calculate gait speed. Time was assessed to the nearest 0.01 s using a manual stopwatch. The walkway was longer than the obligatory 4 or 7 m to prevent participants from slowing down before reaching the required distance. The fastest attempt of 2 trials was used in the present analyses, expressed as gait speed in meters per second [18–20].

Daily-Life Gait Speed Assessments

An Axivity AX3 wearable sensor (Axivity Ltd, Newcastle, UK) featuring a 3-axis accelerometer with a sampling rate of 100 samples/s and range of ±8 g was used to measure daily-life physical activity. The sensor was fixed on the lower back, at an L5 level, directly to the skin using a hypoallergenic adhesive foil. The monitoring period was 7 consecutive days at baseline, and after 6- and 12-month follow-ups. The sensor was waterproof and could therefore be worn during normal showering and bathing. Raw signals were processed using noncommercial uSense system software. The feasibility of uSense system was proved by Fleiner and colleagues [21] in hospitalized persons with dementia. It has the same attachment and sampling frequency as the Axivity sensor, and the software was originally developed in the FARSEEING EU project (PF7 – grant agreement No. 288940) and further improved during the PreventIT EU project (H2020 – grant agreement No. 689238). The software estimates metabolic equivalent [22] and sets a threshold of 1.5 to distinguish sedentary from active bouts [23]. Steps and walking bouts are detected based on acceleration data calculated by an adaptive algorithm, described by Bongartz and colleagues [24], which uses continuously updated amplitude thresholds to achieve high accuracy even at slow walking speeds. A step is detected if the acceleration values reach defined peak thresholds ($E(t)$ = 1.100–1.175) [25]. When a peak is detected as a possible step, the algorithm verifies the peak value, the amplitude, and the stepping frequency as the time between consecutive peaks [25]. The start of a walking episode is identified from the forward acceleration of the lower trunk in agreement with Zijlstra [26] (2004). The validity of gait detection (the detection of walking) has been verified in a population of frail older people older than 75 years, with an overall agreement between the processed accelerometer data and annotated videos of about 92.8% for unscripted walking activities [27]. The walking episodes with a duration of at least 10 s were selected from the raw accelerometer signals. Walking episodes longer than 10 s were divided, processing the middle 10 s-epochs of each walking bout. For each walking epoch of 10 s, daily-life gait speed was estimated based on an inverted pendulum model introduced by Zijlstra and Hof [28]. This method assumes a compass gait type with a circular trajectory of the sensor during each single support phase and determines step length by trigonometry from the peak-to-peak height differences obtained by double integration of the high-pass filtered vertical acceleration [step length = $2\sqrt{((2 \times \text{leg length} \times \text{amplitude of changes in vertical position}) - (\text{amplitude of changes in vertical position}^2))}$]. Leg length was estimated as 53% of body height [29]. MATLAB R2017b (MathWorks, Natick, MA, USA) was used for the analyses and the determination of the gait characteristics.

*Statistical Analyses*

Continuous variables with a Gaussian distribution were presented as mean (standard deviation, SD) and with a non-Gaussian distribution as median [interquartile range, IQR]. A two-tailed $p$ value of <0.05 was considered statistically significant. Outliers were investigated and checked for measurement errors or data-entering errors. If no such error was found, outliers were included in the present analyses. To describe the shape of the individual's daily-life gait speed distribution over the week, we calculated the Ashman's D and the 10th, 25th, 50th, 75th, and 90th percentiles, as presented in Figure 1 [7]. Ashman's $D$ values indicate how well the observed data fit a bimodal distribution. Ashman's $D \geq 2$ indicates a good fit [30].

Interrelation between In-Laboratory and Daily-Life Gait Speed Measures

To investigate the interrelation between in-laboratory gait speed (i.e., 4-m usual pace, 7-m usual pace, and 7-m fast pace gait speed) and daily-life gait speed (i.e., percentiles and peaks) at different time points, Pearson's correlations were calculated. An $r <$ 0.3 was considered negligible, $r$ of 0.3–0.5 was considered low, $r$ of 0.5–0.7 was considered moderate, and $r \geq 0.7$ was considered high [31].

Robustness of In-Laboratory and Daily-Life Gait Speed over Time

A 2-way mixed ANOVA was used to compare mean differences between groups over time, combining a within-subject factor (repeated measures over time, in the present study: baseline, and after 6 months and after 12 months) and a between-subject factor (intervention group). By using a 2-way mixed ANOVA, we investigated the interaction between time and intervention on in-laboratory gait speed measures (4-m usual pace, 7-m usual pace, and 7-m fast pace) as well as daily-life gait speed measures (number of epochs, percentile (P) 50, P90, peak 1, and peak 2). Outliers and normality distribution within cells (time × intervention) were assessed. Homogeneity of variances ($p > 0.05$) and covariances ($p > 0.001$) was assessed by Levene's test of homogeneity and Box's $M$ test, respectively. Mauchly's test of sphericity was used to assess the assumption of sphericity. If violated, the Greenhouse-Geisser estimate was used, and the epsilon (ε) was reported. For the assessment of the first and the second peak (peak 1 and peak 2) in the bimodal distribution of daily-life gait speed, only participants with Ashman $D$'s ≥ 2 on all time points were included in the analyses. Further details of the assumptions to be met allowing to perform a 2-way mixed ANOVA are presented in Appendix A. These analyses were conducted to investigate whether the mean gait speed values (1) were consistent over time and (2) showed no differences between intervention groups. If no differences between intervention groups were present, the subsequent analyses were performed on the entire population.

To investigate the robustness of each type of gait speed measure over time, we calculated the variance components reflecting within-subject (i.e., between measurements: baseline, and after 6 months and after 12 months) and between-subject (i.e., among individuals) variance over time using a repeated measures ANOVA. To calculate these types of variances, the following equations were used:

*Variance within = SS within/k–1*
*Variance between = SS between / N–1*
*with SS = sum of squares; k = number of assessments; n = number of individuals.*

Bland-Altman analyses were performed to visualize the level of agreement between gait speed assessed at baseline and after 12-month follow-up for both in-laboratory and daily-life gait speed measures. Limits of agreement were calculated using the following equation: ±1.96 × SD of the mean difference in gait speed over time. We furthermore checked for systematic differences between slow- and fast-walkers, that is, whether the difference between assessments tends to get larger (or smaller) as the mean increases, in which case data were log-transformed. If systematic differences were still present, a regression approach for nonuniform differences was conducted [32]. In brief, a linear regression analysis was performed between the difference and the mean of the 2 assessments to conduct a "line of best agreement." To calculate the appropriate limits of agreement, first, the residuals from the line of best agreement were plotted as a function of the mean, to see if the standard deviation of the differences was dependent on the mean of the 2 assessments. If there was no relationship between the residuals and the mean, the SD of the difference was regarded as the residual SD from the regression. The limits of agreement for this regression approach were then calculated by adding ± 1.96 × residual SD to the line of best agreement, after which the limits of agreement were judged. Data were analyzed using Statistical Package for the Social Sciences, version 25 (SPSS Inc. Chicago, IL, USA). Visualization of the Bland-Altman analyses was pursued using GraphPad Prism 5.01.

## Results

Baseline characteristics of the included participants are shown in Table 1. The median age of the 189 participants included was 67 (IQR: 64–68) years, and 94 (52.2%) participants were female. Participants had a median number of morbidities of 2 (IQR: 1–3) and used a median of 2 (IQR: 0–4) medications. A total of 29 (15.3%) participants reported a fall in the preceding 6 months. Mean in-laboratory gait speed was 1.39 (0.21), 1.53 (0.24) and 2.07 (0.46) m/s for the 4-m usual, 7-m usual, and 7-m fast gait speed assessments, respectively.

*Interrelation between In-Laboratory and Daily-Life Gait Speed Measures*

Online suppl. Table 1 (for all online suppl. material, see www.karger.com/doi/10.1159/000514150) shows the correlation of in-laboratory gait speed measures and daily-life gait speed measures at 3 different time points as well as mean daily-life gait speed measures. For all time points, negligible to low correlations were found, although overall correlations increased with higher percentiles of daily-life gait speed. The lowest correlation was

**Table 1.** Participant characteristics

| Characteristic | *N* | Baseline |
|---|---|---|
| Age, median [IQR] | 180 | 67 [64–68] |
| Sex, female, *n* (%) | 180 | 94 (52.2) |
| Height, mean (SD) | 183 | 1.71 (0.09) |
| Weight, mean (SD) | 183 | 80 (17) |
| BMI, kg/m$^2$, mean (SD) | 183 | 27.3 (4.55) |
| Units of alcohol/week, median [IQR] | 179 | 3 [1–7] |
| History of falls, past 6 months, *n* (%) | 189 | 29 (15.3) |
| Pain in rest, *n* (%) | 189 | 90 (47.6) |
| Pain while walking, *n* (%) | 189 | 113 (59.8) |
| Number of morbidities, median [IQR] | 183 | 2 [1–3] |
| Number of medications, median [IQR] | 189 | 2 [0–4] |
| 4-m usual, m/s, mean (SD) | 189 | 1.39 (0.21) |
| 7-m usual, m/s, mean (SD) | 189 | 1.53 (0.24) |
| 7-m fast, m/s, mean (SD) | 189 | 2.07 (0.46) |

All variables are presented as *N* (%), unless indicated otherwise. The number of morbidities: presence or history of the following diseases: diabetes mellitus, hypertension, orthostatic hypotension, acute coronary syndrome, myocardial infarction, other ischemic heart diseases, heart failure, atrial fibrillation, cardiac dysrhythmias or arrest, valvular disease, peripheral artery disease, cerebrovascular accident or stroke, transient ischemic attack, arthrosis, rheumatoid arthritis, other arthropathies or joint disorders, dorsopathies, osteoporosis, fractures, cancer, chronic obstructive pulmonary disease, asthma, Parkinson's disease, or epilepsy. IQR, interquartile range; SD, standard deviation.

found for P25 and 7-m fast pace test at 6-month follow-up ($r = 0.045$, $p = 0.599$). The highest correlation was found for P90 and 7-m usual pace test at 6-month follow-up ($r = 0.455$, $p < 0.001$). When comparing the correlations over time, similar patterns and coefficients were observed, indicating a consistent dissonant relationship between in-laboratory gait speed measures and daily-life gait speed measures over time.

*Robustness of In-Laboratory and Daily-Life Gait Speed over Time*

Table 2 shows the descriptives of in-laboratory and daily-life gait speed measures at baseline, and after 6- and 12-month follow-ups. Results of the 2-way mixed ANOVA are also presented in Table 2. All gait speed data (in-laboratory gait speed: 4-m usual, 7-m usual, and 7-m fast, and daily-life gait speed: number of epochs, percentiles, peak 1, and peak 2) were normally distributed. Outliers were included in further analyses. There was no significant main effect of time for any of the in-laboratory or daily-life gait speed measures, except for P90 at different time points, as shown in Table 2. For P90 only, significant differences were found between baseline and 6-month follow-up, and between 6-month and 12-month follow-ups. No statistically significant difference between baseline and 12-month follow-up was present, indicating that the increase in gait speed of P90 at 6-month follow-up was not maintained. No statistically significant interactions between the intervention and time were found on any of the gait speed measures, indicating that the effect of time was independent of the allocated intervention group.

With respect to the variance components of in-laboratory and daily-life gait speed measures over time, the 2 variance components are presented in Table 3. Comparing the different variance components between types of gait speed assessment showed that all gait speed measures had (1) smaller within-subject variance than between-subject variance, and (2) variance components for both in-laboratory and daily-life gait speed in a similar order of magnitude, which was not line with our expectations.

The agreement of in-laboratory and daily-life gait speed measures over time as conducted by Bland-Altman analyses are presented in online suppl. Table 2 and visualized in Figure 2. The mean difference over time for the 4-m usual gait speed, number of epochs, P50, P90, peak 1, and peak 2 was close to zero, showing similar gait speed assessments over time. This was independent of the baseline assessment and independent of the assigned intervention group. For 7-m usual and 7-m fast gait speed, proportional bias was present, showing a relative increase in gait speed over time for slow-walkers and a relative decrease for fast-walkers. All gait speed measures showed wide limits of agreement as the SDs of the mean differences ranged from 0.12 to 0.34 m/s (online suppl. Table 2).

## Discussion

The present study showed that the interrelation between in-laboratory and daily-life gait speed measures showed negligible to low correlations at baseline, and after 6 months and after 12 months, underscoring that these measures are distinct constructs. Robust results of in-laboratory as well as daily-life gait speed measures over 12-month time in this group of high-functioning adults aged 61 to 70 years were observed, independent of the assigned intervention group. Comparison of the variance components revealed smaller within-subject variance than between-subject variance, but in contrast to our expectations, variance components for in-laboratory gait

**Table 2.** Descriptives and 2-way mixed ANOVA of in-laboratory and daily-life gait speed measures over time

| | Baseline, *N* | Baseline | 6 M, *N* | 6 Months | 12 M, *N* | 12 Months | Two-way mixed ANOVA time, *p* value | Two-way mixed ANOVA time × group, *p* value | Two-way mixed ANOVA group, *p* value |
|---|---|---|---|---|---|---|---|---|---|
| 4-m usual, m/s | 189 | 1.39 (0.21) | 156 | 1.40 (0.22) | 136 | 1.40 (0.19) | 0.727 (*N* = 136) | 0.715 (*N* = 136) | 0.780 (*N* = 136) |
| 7-m usual, m/s | 189 | 1.53 (0.24) | 156 | 1.51 (0.21) | 136 | 1.50 (0.20) | 0.126 (*N* = 136) | 0.168 (*N* = 136) | 0.862 (*N* = 136) |
| 7-m fast, m/s | 189 | 2.07 (0.46) | 156 | 2.05 (0.37) | 136 | 2.06 (0.37) | 0.222 (*N* = 136) | 0.907 (*N* = 136) | 0.572 (*N* = 136) |
| P50, m/s | 186 | 0.71 (0.12) | 142 | 0.71 (0.12) | 123 | 0.71 (0.12) | 0.930 (*N* = 116) | 0.678 (*N* = 116) | 0.792 (*N* = 116) |
| P90, m/s | 186 | 1.28 (0.20) | 142 | 1.32 (0.22) | 123 | 1.28 (0.22) | <0.001 (*N* = 116) | 0.222 (*N* = 116) | 0.941 (*N* = 116) |
| Peak 1, m/s | 165 | 1.35 (0.31) | 126 | 1.40 (0.32) | 109 | 1.37 (0.30) | 0.392 (*N* = 92) | 0.183 (*N* = 92) | 0.893 (*N* = 92) |
| Peak 2, m/s | 165 | 0.90 (0.34) | 126 | 0.83 (0.38) | 109 | 0.85 (0.37) | 0.552 (*N* = 92) | 0.312 (*N* = 92) | 0.850 (*N* = 92) |
| Epochs, *n* | 186 | 3,697 (1,301) | 142 | 3,451 (1,347) | 123 | 3,492 (1,291) | 0.327 (*N* = 116) | 0.622 (*N* = 116) | 0.986 (*N* = 116) |

All variables are presented as mean (SD). The fastest attempt of 2 walks for the in-laboratory gait speed measures was used. SD, standard deviation.

**Table 3.** Comparison between the within-subject variance and the between-subject variance

| Measure | Within-subject variance | Between-subject variance |
|---|---|---|
| In-laboratory gait speed measures, m/s | | |
| 4-m usual pace | 0.005 | 0.097 |
| 7-m usual pace | 0.027 | 0.119 |
| 7-m fast pace | 0.075 | 0.397 |
| Daily-life gait speed measures, m/s | | |
| P50 | 0.001 | 0.032 |
| P90 | 0.095 | 0.121 |
| Peak 1 | 0.026 | 0.176 |
| Peak 2 | 0.044 | 0.331 |

P, percentile.

speed measures were comparable to those of daily-life gait speed measures. These findings suggest that both these types of gait speed measures show distinct personal features: despite the heterogeneity in absolute gait speed measures across participants, both in-laboratory and daily-life gait speed measures were not susceptible to change over 12 months.

*Interrelation between In-Laboratory and Daily-Life Gait Speed Measures*

The literature on the comparison or interrelation of in-laboratory and daily-life gait speed is limited. Recently, a study comparing multiple in-laboratory gait speed measures and daily-life gait speed was performed in slow-walking sarcopenic older adults [33]. Short bouts of daily-life gait speed were compared to the in-laboratory 4-m gait speed test, whereas longer bouts of daily-life gait speed were compared to the 6-min walking test (6MWT) and 400-m walking test (400MWT). Low to moderate correlations between daily-life gait speed and in-laboratory gait speed ($r$ = 0.23, 0.48, and 0.59 for the 4-m gait speed, 6MWT, and 400MWT, respectively) are in line with our study and thereby underscore that these measures are distinct constructs. However, the findings in the previous study do suggest that the assessment of gait speed using longer gait tests is more representative for daily-life gait speed [33]. In the present study, we did not show a difference between the 4- and 7-m gait speed tests and their relation with daily-life gait speed measures. This might be explained by the fact that the 7-m gait speed tests are still relatively short gait speed tests compared to the 6MWT and 400MWT. Our main interest was to explore if, and how, the correlation between in-laboratory and daily-life gait speed would change over time. Despite low cross-sectional correlations, a relative change in one measure could be accompanied by a similar change in the other measure, indicating that a change in performance would affect behavior, and vice versa. However, no relation in changes of gait speed measures over time was found, indicating an even lower correlation between the 2 constructs of gait function, and therefore, in-laboratory and daily-life gait speed measures could be considered distinct personal features.

*Robustness of In-Laboratory and Daily-Life Gait Speed Measures over Time*

The level of agreement for both in-laboratory and daily-life gait speed measures showed relatively wide limits of agreement. A clinically relevant change in in-laboratory

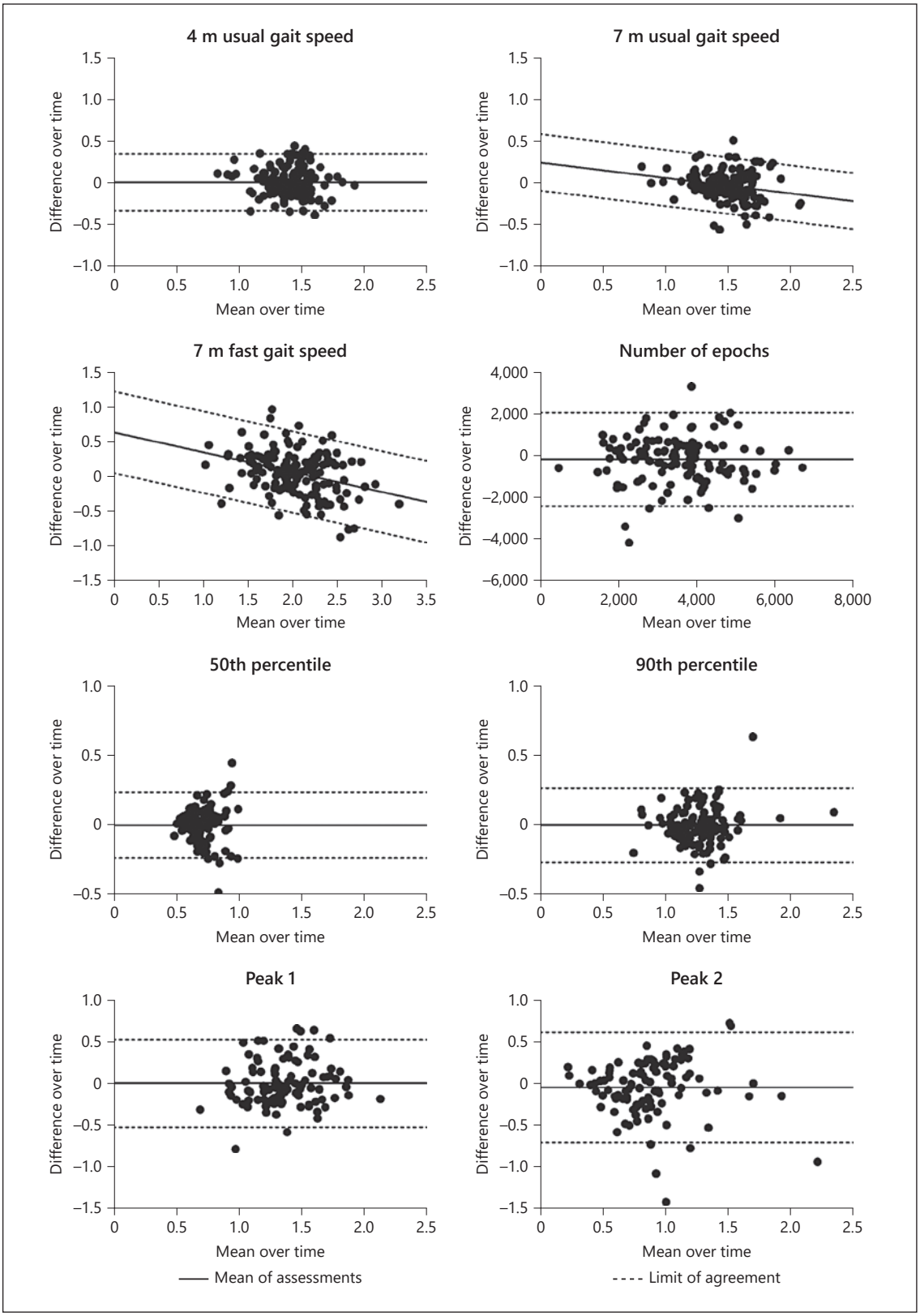


**Fig. 2.** Bland-Altman analyses of in-laboratory and daily-life gait speed measures over time (i.e., 12-month follow-up and baseline assessment).

gait speed usually lies between 0.1 and 0.2 m/s in older adults [3, 34] and adults after a stroke, a hip fracture, or other pathologies [35]. Our data revealed that the limits of agreement for all gait speed measures are well beyond these limits of a clinically relevant change as the SD of the mean differences ranged from 0.12 to 0.34 m/s. This might indicate that intervention effects in future studies need to show a relatively large change to be able to value effect sizes on its importance, showing results beyond measurement errors. However, the reported clinically relevant changes in in-laboratory gait speed were not assessed in this specific population of healthy, high-functioning adults and could therefore not be translated without caution.

*Limitations and Implications*

Some limitations need to be taken into account. First, we included a relatively well-functioning population of adults aged 61 to 70 years, participating in a lifestyle intervention study, which could introduce a ceiling effect due to their high level of performance. Initially, we expected significant changes over time in the intervention groups when compared to the control group allowing us to investigate whether changes in 1 gait speed measure would be related to changes in the other measurement type. However, the possible effect of the intervention was investigated thoroughly and showed no significant effect on both in-laboratory and daily-life gait speed measures. Moreover, the follow-up period was relatively short for such a well-functioning sample, so a decline in gait speed might not be expected. Regular assessments of physical performance and gait speed are often recommended as part of follow-up measures in clinical practice, or to see whether temporal changes are associated with treatment regimen in intervention studies. However, the present study shows that measuring both in-laboratory and daily-life gait speed measures only once in a period of 1 year seems sufficient in a high-functioning population of adults aged 61 to 70 years. Future research should focus on investigating the interrelation between in-laboratory and daily-life gait speed measures in (pre-)frail populations.

Furthermore, in the present analyses, a 10-s epoch time frame was chosen to reliably estimate daily-life gait speed measures, as previously described by Rispens et al. [36]. It may be argued that this epoch time is rather long, in comparison to the in-laboratory gait speed tests. However, by using this epoch time, we believe to capture walking behavior similar to walking behavior evoked during the in-laboratory measurement methods, that is, "optimal walking." By selecting shorter epoch lengths, mostly in-house walking would be captured and therewith walking behavior that most likely resembles "shuffling." On the other hand, selecting a longer epoch time most likely resembles walking episodes outdoors. Outdoor walking and therewith gait speed is highly dependent on behavioral and environmental factors [37, 38] which could not be taken into account in this study. The model of Zijlstra & Hof [26] was used to estimate speed; however, this method was developed to estimate speed during steady-state walking. We believe our method of determining steady-state walking epochs sufficiently approximates steady-state conditions; however, it is possible that some nonsteady or nonstraight walking behavior (e.g., turns) are present in a relatively small proportion of the epochs. Nevertheless, a systematic exploration of the effect of different epoch lengths on the interrelation between in-laboratory and daily-life gait is warranted for future implementation of the combined use of in-laboratory and daily-life gait speed measures in clinical practice. Because daily-life gait speed is dependent on behavioral and environmental factors, the added value could be that daily-life gait speed states more about actual physical activity and physical performance behavior in everyday life. To further understand and make (clinical) use of such information, daily-life gait speed measures may be combined in future studies with more advanced measuring equipment, as for example GPS, in-home cameras, or the concept of "lifelogging" [39], to monitor what people do in the real world, which walking distances are covered, and under which circumstances.

## Conclusion

In-laboratory and daily-life gait speed measures are distinct and robust constructs over 12 months, implying that gait speed represents a robust personal feature in a population of high-functioning adults aged 61 to 70 years. Future research should focus on the use of the combination of both measures in clinically relevant populations to investigate the potential added value in predicting health outcomes by gaining insights into actual daily-life physical behavior.

## Appendix

*Results of the Assumption to Perform a Two-Way Mixed ANOVA*

Normality of gait speed measures within the different intervention groups at different time points was not always present. Homogeneity of variances and covariances was present in all gait

speed measures. Mauchly's test of sphericity indicated that the assumption of sphericity was met for the two-way interaction for the 4-m usual gait speed: $X^2$ (2) 5,689, $p = 0.058$ but not for the 7-m usual gait speed: $X^2$ (2) 18,238, $p < 0.001$ and 7-m fast pace gait speed: $X^2$ (2) 38,080, $p < 0.001$. For daily-life gait speed measures the assumption was met for all measures: number of epochs: $X^2$ (2) 0,211, $p = 0.900$; P50: $X^2$ (2) 4,942, $p = 0.084$; peak 1: $X^2$ (2) 4,708, $p = 0.095$; peak 2: $X^2$ (2) 5,498, $p = 0.064$, but not for P90: $X^2$ (2) 8,816, $p = 0.012$.

## Statement of Ethics

The research and manuscript are in compliance with ethical standards. The study and methods were evaluated and approved by the Ethical Committees in Norway (#2016/1891), Stuttgart (#770/2016B01), and Amsterdam (#2016.539; Dutch Trial Registry NL59977.029.16). All participants signed written informed consent.

## Conflict of Interest Statement

The authors declare that there are no conflicts of interest.


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