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Research Article

Distinct Trajectories of Individual Physical Performance Measures Across 9 Years in 60- to 70-Year-Old Adults

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Abstract

Background: Physical performance is an important factor for successful aging. This study aimed to identify distinct trajectories of multiple physical performance measures over 9 years in individuals aged 60–70 years and to evaluate their characteristics and the overlap between measures.

Methods: Four physical performance measures were assessed in 440 participants of the Longitudinal Aging Study Amsterdam: tandem stand, gait speed, chair stand, and handgrip strength. Gender-specific latent class models were conducted to obtain distinct trajectories and their degree of overlap.

Results: Mean age at baseline was 67.9 (*SD* 1.7) years for males and 68.0 (*SD* 1.7) years for females. The optimal number of trajectories differed across measures. For tandem stand, no distinct trajectories were found (all 179 males, 198 females). For gait speed, three trajectories were identified, dependent on baseline speed: high-stable (47 males, 27 females), intermediate-stable (132 males, 130 females), and low-declining performance (6 males, 48 females). Two trajectories were identified for the chair stand: a stable (168 males, 150 females) and declining trajectory (10 males, 38 females). For handgrip strength, three declining trajectories were identified differing in baseline performance: high (55 males, 75 females), intermediate (111 males, 118 females), and low (17 males, 10 females). Overall, 11.9% of males and 5.7% of females were classified in similar trajectories across measures.

Conclusions: Trajectories of physical performance were heterogeneous, but showed similar patterns for males and females. Little overlap between measures was shown, suggesting different mechanisms for decline. This study emphasizes the use of multiple domains to assess physical performance.

Keywords: Physical functional performance, Latent class growth models, Walking speed, Handgrip strength, Chair stand

Background

Physical performance is an important factor for successful aging. Different measures are commonly used to assess the multiple domains of physical performance known as mobility, balance, and muscle strength. These measurement methods include the tandem stand, gait speed, chair stand test, and the assessment of handgrip strength and are found to be valid and reliable tests (1,2). It is known from both cross-sectional as well as longitudinal studies that low performance on these measures are associated with negative health outcomes such as poor cognitive functioning (3,4), mobility

limitations, disabilities in activities of daily living (3–7), hospitalization (6,8), and mortality (9–11).

The decline in physical performance with chronological age is a dynamic process and the timing and manner in which the decline starts differs between individuals and performance measure. To illustrate, distinct trajectories have been described previously in older individuals for gait speed; a slow, moderate, and fast-declining trajectory (12). Although all participants of that study were considered to be well-functioning at the start of the study, the study clearly showed that the pace of decline varied across individuals. Another study investigated the Short Physical Performance Battery-score (SPPB) (13) and identified a slow-declining, a fast-declining, and a stable subgroup in their cohort of older Mexican Americans. For both outcomes, older age was found to be the most important determinant of belonging to the fast-declining group. However, these previous studies were conducted among people aged 75 and older at baseline and additionally use only one measure or score. Studies combining multiple physical performance measures among the younger old are lacking. Unraveling the course of multiple physical performance measures in a younger old population is important as underlying patterns of change precede absolute values of physical performance measures. This is known as "the horse racing effect" (14). By researching these trajectories and their overlap in a population of older people aged 60–70 years old, in whom limitations in physical performance are still uncommon or unnoticed, a better identification of those at risk for a decline in physical performance and therefore a better identification of those most likely to benefit future interventions is undertaken.

Therefore, this study aimed to identify distinct trajectories of multiple individual physical performance measures, as assessed by tandem stand, gait speed, chair stand, and handgrip strength, over 9 years follow-up and to additionally evaluate their characteristics and overlap in individuals aged 60–70 years old.

Methods

Study Sample

We included data from the Longitudinal Aging Study Amsterdam (LASA) (15). The LASA study is an ongoing cohort study in a representative sample of 3,107 Dutch older persons and focuses on predictors and consequences of changes in physical, cognitive, emotional, and social functioning. The Medical Ethics Committee of the VU University Medical Center Amsterdam approved the study prior to each follow-up round of measurements. Participants were selected from population registries in 11 municipalities in the Netherlands and the sample was stratified for age, sex, and level of urbanization. The first measurement cycle was completed in 1992–1993 and subsequent measurement cycles were 3 years apart. In this study, we included the data from 440 participants aged 60–70 years who participated in the second, third, fourth, and fifth measurement cycle from 1995 to 1996 onwards, as all physical performance measures were assessed from then on. Only participants providing two or more measurements on the physical performance measures across the four time points were included in the analysis for that specific outcome (16).

Measurements

We used data on four different physical performance measures across four time points in LASA (9 years follow-up) as outcome measures: (i) tandem stand, (ii) gait speed, (iii) five repeated chair stand test, and (iv) handgrip strength. The tandem stand was used to measure standing balance. Participants were asked to maintain their feet in a tandem position (heel-to-toe) for 10 seconds (17). Time was recorded to the nearest second, with more time reflecting better performance.

Gait speed was assessed on a track of three meters. Participants were asked to walk 3 m, turn around and walk back for 3 m, as quickly as possible. Time needed to complete the test was recorded to the nearest second and divided by 6 m to obtain an assessment of speed in m/s, with high speed reflecting better performance.

The chair stand test was assessed by asking participants to stand up from sitting position on a chair and sit down five times, at usual pace, with their arms folded across their chest (17). Time needed to perform five repetitions was recorded to the nearest second, with less time reflecting better performance.

Handgrip strength was used as a physical performance measure of the upper extremities and was measured with a handheld dynamometer (Takei TKK 5001, Takei Scientific Instruments Co. Ltd., Tokyo, Japan). The measurement was performed with repeated measurements of two attempts per hand, while participants were in standing position with their arms along their body. The maximum value out of four attempts (in kg) was used for the analyses, with high strength reflecting better performance.

Baseline measurements considered for the descriptive analysis included sex, age (years), self-reported physical activity (in minutes/week, using the validated LASA Physical Activity Questionnaire (18)), smoking behavior (never smoker/current smoker/former smoker), alcohol consumption (glasses of alcohol per week), number of medications, fall history in the previous year (yes/no), cognitive functioning (assessed with Mini-Mental State Examination [MMSE]) (19), and depressive symptoms (assessed with the Center for Epidemiologic Studies-Depression scale [CES-D]) (20). Multimorbidity was defined as the self-reported presence of two or more chronic diseases including cardiovascular disease, peripheral artery disease, diabetes mellitus, cerebrovascular accident or stroke, chronic obstructive pulmonary disease, arthritis, or cancer.

Statistical Analysis

Statistical analyses were conducted using the Mplus 7.11 and IBM SPSS Statistics for Windows, Version 23.0., Armonk, NY, IBM Corp software packages. The analyses for the current study consisted of two steps, described in detail below. Analyses were conducted separately for males and females and separately for each of the four physical performance measures. Stratification by sex was based on previous studies as well as on analyses on the same cohort (16,21).

First, distinct trajectories of physical performance were analyzed with latent class growth modeling (LCGM). LCGM is a contemporary longitudinal technique and is an extension of conventional growth modeling. In conventional analyses, the assumption that all individuals in the study sample come from a single population must hold meaning that one (average) trajectory will adequately describe the developmental pattern of the sample. This assumption is relaxed in LCGM, meaning that individuals in the sample do not need to come from one single underlying population, but can come from multiple, underlying (or latent) subpopulations. Identifying the number and characteristics of these underlying subpopulations is the main aim of LCGM. This is done by identifying k number of distinct latent classes (ie, subgroups) of, in the present study, trajectories of physical performance measures. Each identified class has its own specific growth parameters (intercept, slope), which are also assumed to be unobserved, or latent.

To determine the optimal number of latent classes, we used the Bayesian Information Criterion (BIC). The BIC is commonly used within LCGM, considering both the likelihood of the model as well as the number of parameters in the model; a lower BIC value indicates a better model fit (a decrease of at least 10 points usually denotes a sufficient improvement). Second, we considered the Bootstrapped Likelihood Ratio Test (BLRT; lower *p*-values indicate better model fit). To further determine the optimal number of classes, we looked at the posterior probabilities for each individual in the sample, the entropy (favoring models with values closest to 1) and clinical interpretability.

In step 2, for all subgroups identified with the LCGM for the trajectories of tandem stand (one subgroup), gait speed (three subgroups), chair stands (two subgroups), and handgrip strength (three subgroups), we performed a descriptive analysis of baseline characteristics. Baseline values were described as mean ± standard deviation (*SD*) for normally distributed variables, median (interquartile range [IQR]) for variables with skewed distribution, and frequencies (%) for categorical variables. To describe the characteristics and differences therein between trajectories of one measure, we used the independent samples *t*-test (normally distributed variables), Mann–Whitney *U*-test (variables with skewed distribution), or Fisher's Exact Test (frequencies) when comparing two trajectories. For comparison of three trajectories, we used a one-way analysis of variance (ANOVA) (normally distributed variables), Kruskal–Wallis ANOVA (variables with skewed distribution), or Chi-square test (frequencies). Significance level was set at α = 0.05. Results of the latent class growth models were reported taking into account the GRoLTS-Checklist: Guidelines for Reporting on Latent Trajectory Studies (22) to ensure transparency and facilitate replicability of our findings.

Results

A total of 440 participants were included (212 males and 228 females). Mean age at baseline was 67.9 (*SD* 1.7) and 68.0 (*SD* 1.7) years for males and females, respectively. Supplementary Table 1 (Supplementary Material) shows the descriptive baseline participant characteristics stratified for sex.

All models for the latent class growth models are specified as unconditional models. We opted for unconditional models and investigating risk factors in a next step. It has been shown that conditional models often affect class formation in such a way that the identified classes lose their intended interpretation, leading to flawed results. Moreover, as suggested by and further explained in the GRoLTS-checklist (see van de Schoot et al. (22), it is difficult to not mix up the problem of investigating predictors of class membership with the problem of finding the optimal number of classes.

Figure 1 demonstrates the trajectories that were identified for the tandem stand, gait speed, chair stand, and handgrip strength measures. The optimal number of trajectories differed across measures. The tandem stand demonstrated relatively little heterogeneity in decline; the optimal model resulted in one declining trajectory for males (*N* = 179) as well as for females (*N* = 198). We identified three trajectories for gait speed: high baseline speed with no decline (47 males, 27 females), intermediate baseline speed with no decline (132 males, 130 females), and low baseline speed with decline (6 males, 48 females). The analyses for chair stand revealed that the optimal model consisted of two trajectories, one small subgroup showing declining performance over time (10 males, 38 females) and one fairly stable group with no decline (168 males, 150 females). For
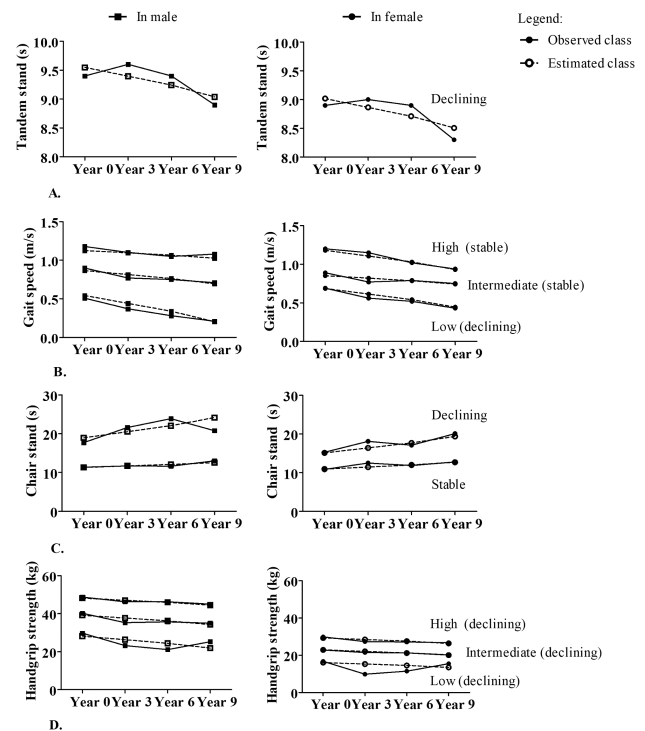
Figure 1. Identified trajectories of physical performance measures.

handgrip strength, three declining trajectories were identified based on their baseline performance: high strength (55 males, 75 females), intermediate strength (111 males, 118 females), and low strength (17 males, 10 females). Detailed information regarding model fit is presented on Open Science Framework (https://osf.io/q2tbw/) as well as additional results according to the GRoLTS-Checklist: Guidelines for Reporting on Latent Trajectory Studies (22).

Descriptive characteristics per physical performance measure and for each identified trajectory are presented in Supplementary Table 2 and Tables 1–3. Supplementary Table 2 shows the characteristics of the population stratified by sex to describe one trajectory of tandem stand performance. Little to moderate differences between males and females were found for the other measures of physical performance: for gait speed 0.95 (0.25) m/s (males) versus 0.87 (0.24) m/s (females), for chair stand 11.8 (*SD* 3.3) seconds (males) versus 12.1 (*SD* 3.5) seconds (females) and for handgrip strength 42.2 (*SD* 7.0 kg) (males) versus 25.1 (*SD* 4.8) kg (females).

Table 1 shows the characteristics of the population, stratified by sex and the three gait speed trajectories. For both males and females, the most unfavorable trajectory of low and declining gait speed was similar in shape. This trajectory consisted of relatively fewer males than females. Additionally, females in the low declining trajectory were on average the oldest compared to the females in the other two trajectories. Comparing the other performance measures, differences were visible between the trajectories for both males and females: participants classified into the low speed, declining trajectory performed worse on all other performance measures at baseline, although differences between the trajectories were not equally profound for all measures.

Table 2 shows the characteristics of the population stratified by sex and the two chair stand trajectories. For both males and females, a similar shape in the declining (ie, low speed) trajectory was

Table 1. Characteristics for the Subgroups Classified in Distinct Trajectories of Gait Speed in Community-Dwelling Adults of 60–70 Years

	Males (N = 185)				Females (N = 205)			
	Low, declining (n = 6, 3.2%)	Intermediate, stable (n = 132, 71.4%)	High, stable (n = 47, 25.4%)	p-value*	Low, declining (n = 48, 23.4%)	Intermediate, stable (n = 130, 63.4%)	High, stable (n = 27, 13.2%)	p-value*
Gait speed, m/s								
Baseline	0.51 ± 0.16	0.90 ± 0.18	1.18 ± 0.28	<.001	0.69 ± 0.17	0.89 ± 0.19	1.20 ± 0.19	<.001
3-y follow-up	0.37 ± 0.07	0.77 ± 0.17	1.10 ± 0.23	<.001	0.56 ± 0.17	0.77 ± 0.16	1.15 ± 0.21	<.001
6-y follow-up	0.28 ± 0.07	0.75 ± 0.19	1.05 ± 0.22	<.001	0.52 ± 0.16	0.79 ± 0.16	1.02 ± 0.21	<.001
9-y follow-up	0.21 ± 0.04	0.71 ± 0.18	1.08 ± 0.17	<.001	0.43 ± 0.13	0.75 ± 0.15	0.94 ± 0.13	<.001
Clinical variables at baseline								
Age, years	68.3 ± 2.5	68.0 ± 1.6	67.7 ± 1.6	.439	68.8 ± 1.8	67.7 ± 1.5	67.9 ± 1.9	.001
Number of medications	4 (2–6)	2 (1–3)	2 (1–3)	.142	2.5 (1–4)	2 (1–3)	1 (1–3)	.327
Multimorbidity[a]	2 (33.3%)	30 (22.7%)	10 (21.3%)	.802	16 (33.3)	29 (22.3)	6 (22.2)	.302

	Males (N = 185)				Females (N = 205)			
	Low, declining (n = 6, 3.2%)	Intermediate, stable (n = 132, 71.4%)	High, stable (n = 47, 25.4%)	p-value*	Low, declining (n = 48, 23.4%)	Intermediate, stable (n = 130, 63.4%)	High, stable (n = 27, 13.2%)	p-value*
Cognitive functioning, MMSE score (0–30)	28 (26–29)	28 (27–29)	29 (27–29)	.328	28 (27–29)	28 (27–29)	28 (27–29)	.852
Depressive symptoms present (>16 CES-D)	0 (0%)	6 (4.5%)	1 (2.1%)	.666	8 (16.7%)	16 (12.3%)	1 (3.7%)	.258
≥1 fall within last 12 mo	3 (50.0%)	40 (30.3%)	12 (25.5%)	.450	13 (27.1%)	43 (33.1%)	6 (22.2%)	.462
Lifestyle variables at baseline								
Physical activity, LAPAQ score, minute/week	758 ± 661	1,093 ± 753	1,017 ± 585	.465	1,337 ± 714	1,477 ± 737	1,339 ± 582	.409

	Males (N = 185)				Females (N = 205)			
	Low, declining (n = 6, 3.2%)	Intermediate, stable (n = 132, 71.4%)	High, stable (n = 47, 25.4%)	p-value*	Low, declining (n = 48, 23.4%)	Intermediate, stable (n = 130, 63.4%)	High, stable (n = 27, 13.2%)	p-value*
Smoking behavior								
Never smoker	0 (0%)	13 (9.8%)	7 (14.9%)	.379	24 (50.0%)	63 (48.5%)	13 (48.1%)	.517
Former smoker	4 (66.7%)	87 (65.9%)	34 (72.3%)		12 (25.0%)	43 (33.1%)	11 (40.7%)	
Current smoker	2 (33.3%)	32 (24.2%)	6 (12.8%)		12 (25.0%)	24 (18.5%)	3 (11.1%)	
Glasses alcohol/week	0.5 (0–15)	6 (3–21)	6 (3–21)	0.166	2 (0.5–7)	1 (0–6)	3 (1–7)	.160
Physical performance-related variables at baseline								
Unable to perform tandem stand for 10 s	4 (66.7%)	14 (10.6%)	9 (19.1%)	<.001	21 (43.8%)	24 (18.5%)	7 (25.9%)	.003
Chair stands, s	20.7 ± 6.5	12.3 ± 3.1	10.0 ± 2.2	<.001	14.1 ± 4.8	11.7 ± 2.9	10.8 ± 1.9	<.001
Handgrip strength, kg	32.5 ± 13.1	42.0 ± 7.3	42.8 ± 6.1	.005	23.6 ± 5.0	25.6 ± 4.6	25.8 ± 4.5	.033

Note: CES-D = Center for Epidemiologic Studies-Depression; LAPAQ = LASA physical activity questionnaire; MMSE = Mini-Mental State Examination.

[a]Multimorbidity defined as ≥2 of the following chronic diseases: cardiovascular disease, peripheral artery disease, diabetes mellitus, cerebrovascular accident or stroke, chronic obstructive pulmonary disease, arthritis, and cancer. Data are presented as mean ± *SD*, *n* (%), or median (IQR).

*One-way ANOVA for normally distributed variables, Kruskal–Wallis ANOVA for non-normally distributed variables, Chi-square for frequencies.

obtained and this trajectory consisted of fewer males (5.6%) than females (20.2%). Additionally, both males and females in the declining trajectory were on average older compared to their counterparts in the other trajectory. For females, the presence of multimorbidity was higher in the declining trajectory. Comparing the other performance measures, differences between the trajectories were visible for both males and females: participants classified into the most unfavorable, declining trajectory performed worse on all other performance measures at baseline although differences between the trajectories were not equally profound for all measures.

Table 3 shows the characteristics of the population stratified by sex and the three trajectories of handgrip strength. For males and females, three trajectories were obtained that were similar in shape but differing in low, intermediate, and high baseline performance. The most unfavorable (ie, the low baseline handgrip strength) trajectory consisted of relatively more males (9.3%) than females (4.9%). Additionally, both males and females in the low trajectory were on average older compared to their counterparts in the other trajectories. Comparing the other performance measures, differences are visible between the trajectories for both males and females:

Table 2. Characteristics for the Subgroups Classified in Distinct Trajectories of Chair Stand Performance in Community-Dwelling Adults of 60–70 Years

	Males (N = 178)			Females (N = 188)		
	Declining (*n* = 10, 5.6%)	Stable (*n* = 168, 94.4%)	*p*-value*	Declining (*n* = 38, 20.2%)	Stable (*n* = 150, 79.8%)	*p*-value*
Chair stand, s						
Baseline	17.7 ± 5.0	11.4 ± 2.8	.006	15.3 ± 3.3	10.9 ± 1.7	<.001
3-y follow-up	21.6 ± 7.1	11.7 ± 2.7	.003	18.1 ± 7.1	12.5 ± 2.6	.002
6-y follow-up	23.9 ± 6.5	11.6 ± 2.6	.077	17.1 ± 2.7	11.9 ± 2.6	<.001
9-y follow-up	20.8 ± 3.9	13.0 ± 3.1	<.001	20.1 ± 4.1	12.8 ± 2.5	<.001
Clinical variables at baseline						
Age, years	69.2 ± 1.7	67.9 ± 1.6	.011	68.3 ± 1.7	67.9 ± 1.7	.156
Number of medications	3 (2–5)	2 (1–3)	.071	2.5 (1–5)	2 (1–3)	.029
Multimorbidity[a]	2 (20.0%)	36 (21.4%)	.915	13 (34.2)	29 (19.4)	.049
Cognitive functioning, MMSE score (0–30)	28 (26–29)	28 (27–29)	.362	29 (28–30)	28 (27–29)	.003

	Males (N = 178)			Females (N = 188)		
	Declining (*n* = 10, 5.6%)	Stable (*n* = 168, 94.4%)	*p*-value*	Declining (*n* = 38, 20.2%)	Stable (*n* = 150, 79.8%)	*p*-value*
Depressive symptoms present (>16 CES-D)	2 (20.0%)	5 (3.0%)	.051	8 (21.1%)	12 (8.0%)	.035
≥1 fall within last 12 mo	4 (40.0%)	47 (28.0%)	.475	14 (36.8%)	41 (27.3%)	.318
Lifestyle variables at baseline						
Physical activity, LAPAQ score, minute/week	878 ± 520	1,087 ± 722	.395	1,317 ± 570	1,478 ± 753	.222
Smoking behavior						
Never smoker	1 (10.0%)	19 (11.3%)	0.215	20 (52.6%)	71 (47.3%)	.789
Former smoker	9 (90.0%)	111 (66.1%)		11 (28.9%)	52 (34.7%)	
Current smoker	0 (0%)	38 (22.6%)		7 (18.4%)	27 (18.0%)	
Glasses alcohol/week	10 (2–23)	6 (3–21)	0.462	2 (0.5–6)	2 (0.5–6)	.972

	Males (N = 178)			Females (N = 188)		
	Declining (*n* = 10, 5.6%)	Stable (*n* = 168, 94.4%)	*p*-value*	Declining (*n* = 38, 20.2%)	Stable (*n* = 150, 79.8%)	*p*-value*
Physical performance-related variables at baseline						
Unable to perform tandem stand for 10 s	0 (0%)	24 (14.3%)	.362	8 (21.1%)	37 (24.7%)	.677
Gait speed, m/s	0.81 ± 0.17	0.98 ± 0.25	.031	0.79 ± 0.20	0.92 ± 0.23	.002
Handgrip strength, kg	37.3 ± 4.2	42.6 ± 7.1	.021	24.6 ± 5.0	25.6 ± 4.7	.288

Note: CES-D = Center for Epidemiologic Studies-Depression; LAPAQ = LASA physical activity questionnaire; MMSE = Mini-Mental State Examination.

[a]Multimorbidity defined as ≥2 of the following chronic diseases: cardiovascular disease, peripheral artery disease, diabetes mellitus, cerebrovascular accident or stroke, chronic obstructive pulmonary disease, arthritis, and cancer.

Data are presented as mean ± SD, *n* (%), or median (IQR).

*Independent samples *t*-test for normally distributed variables, Mann–Whitney *U*-test for non-normally distributed variables, Fisher's Exact Test for frequencies.

participants classified into the low trajectory performed worse on baseline gait speed measures, and females showed a higher inability to maintain a tandem stand for ten seconds. These differences between the trajectories were not equally profound for all measures. No other characteristics such as number of medications, the presence of multimorbidity, cognitive functioning, depressive symptoms, a history of falls or present lifestyle factors at baseline associated consistently between the most unfavorable trajectories across measures.

Table 4 shows the overlap between the trajectories obtained by each physical performance measure. There is little to medium overlap between the most unfavorable as well as the most favorable trajectories in both males and females: 19.7–60.1% of participants were classified in similar trajectories when two measures were compared. In total, only 34 participants (22 males, 12 females) were classified

in a similar trajectory of the three physical performance measures, showing a total overlap of 5.7–11.9%.

Discussion

The present study shows that for 60-to-70-year olds, the development of physical performance as measured by the tandem stand, gait speed, the chair stand test, and handgrip strength is relatively heterogeneous over time. Only few participants showed a decline in physical performance over time and surprisingly, little differences in trajectories and describing characteristics between males and females were observed. The optimal number of trajectories did differ by physical performance measure: one trajectory of tandem stand was identified as the best fitting model, the optimal number for

Table 3. Characteristics for the Subgroups Classified in Distinct Trajectories of Decline in Handgrip Strength in Community-Dwelling Adults of 60–70 Years

	Males (N = 183)				Females (N = 203)			
	Low, declining (n = 17, 9.3%)	Intermediate, declining (n = 111, 60.7%)	High, declining (n = 55, 30.0%)	p-value*	Low, declining (n = 10, 4.9%)	Intermediate, declining (n = 118; 58.1%)	High, declining (n = 75, 37.0%)	p-value*
Handgrip strength, kg								
Baseline	29.8 ± 5.8	40.2 ± 4.5	48.8 ± 5.7	<.001	16.8 ± 3.4	22.9 ± 2.5	29.9 ± 2.8	<.001
3-y follow-up	23.3 ± 5.4	35.3 ± 5.6	46.3 ± 5.5	<.001	9.9 ± 6.4	21.5 ± 5.0	27.4 ± 4.4	<.001
6-y follow-up	21.1 ± 5.5	35.8 ± 5.4	46.3 ± 5.6	<.001	11.5 ± 7.2	21.3 ± 4.7	27.1 ± 5.2	<.001
9-y follow-up	25.3 ± 4.7	35.0 ± 4.6	45.0 ± 4.4	<.001	15.5 ± 0.6	20.2 ± 3.1	26.8 ± 3.1	<.001
Clinical variables at baseline								
Age, years	68.6 ± 1.9	68.0 ± 1.6	67.4 ± 1.6	.008	69.1 ± 1.8	68.1 ± 1.8	67.6 ± 1.5	.010
Number of medications	2 (2–4)	2 (1–4)	2 (1–2)	.034	3 (1–5.8)	2 (1–4)	1 (1–3)	.058
Multimorbidity[a]	2 (11.8%)	31 (27.9%)	8 (14.5%)	.082	3 (30.0%)	36 (30.5%)	12 (16.0%)	.072

	Males (N = 183)				Females (N = 203)			
	Low, declining (n = 17, 9.3%)	Intermediate, declining (n = 111, 60.7%)	High, declining (n = 55, 30.0%)	p-value*	Low, declining (n = 10, 4.9%)	Intermediate, declining (n = 118; 58.1%)	High, declining (n = 75, 37.0%)	p-value*
Cognitive functioning, MMSE score (0–30)	28 (25–29)	28 (27–29)	29 (27–29)	.218	28 (27–29)	28 (27–29)	29 (27–29)	.383
Depressive symptoms present (>16 CES-D)	3 (17.6%)	3 (2.7%)	1 (1.8%)	.008	2 (20.0%)	17 (14.4%)	5 (6.7%)	.181
≥1 fall within last 12 mo	6 (35.3%)	33 (29.7%)	16 (29.1%)	.882	3 (30.0%)	36 (30.5%)	23 (30.7%)	.999
Lifestyle variables at baseline								
Physical activity, LAPAQ score, minute/week	1,363 ± 976	1,035 ± 740	1,034 ± 549	.216	1,508 ± 816	1,371 ± 652	1,499 ± 786	.449

	Males (N = 183)				Females (N = 203)			
	Low, declining (n = 17, 9.3%)	Intermediate, declining (n = 111, 60.7%)	High, declining (n = 55, 30.0%)	p-value*	Low, declining (n = 10, 4.9%)	Intermediate, declining (n = 118; 58.1%)	High, declining (n = 75, 37.0%)	p-value*
Smoking behavior								
Never smoker	4 (23.5%)	8 (7.2%)	8 (14.5%)	.162	5 (50.0%)	56 (47.5%)	38 (50.7%)	.760
Former smoker	8 (47.1%)	80 (72.1%)	36 (65.5%)		4 (40.0%)	37 (31.4%)	26 (34.7%)	
Current smoker	5 (29.4%)	23 (20.7%)	11 (20.0%)		1 (10.0%)	25 (21.2%)	11 (14.7%)	
Glasses alcohol/week	2 (0–18)	6 (3–21)	7 (6–21)	.139	0.5 (0–3)	2 (0–7)	1 (0.5–6)	.488
Physical performance-related variables at baseline								
Unable to perform tandem stand for 10 s	4 (23.5%)	14 (12.6%)	7 (12.7%)	.468	5 (50.0%)	22 (18.6%)	23 (30.7%)	.030
Chair stand, s	13.0 ± 3.7	12.1 ± 3.4	11.0 ± 3.1	.064	12.8 ± 2.9	12.5 ± 3.9	11.8 ± 3.0	.427
Gait speed, m/s	0.84 ± 0.26	0.92 ± 0.23	1.08 ± 0.27	<.001	0.72 ± 0.34	0.84 ± 0.20	0.95 ± 0.25	.001

Note: CES-D = Center for Epidemiologic Studies-Depression; LAPAQ = LASA physical activity questionnaire; MMSE = Mini-Mental State Examination.

[a]Multimorbidity defined as ≥2 of the following chronic diseases: cardiovascular disease, peripheral artery disease, diabetes mellitus, cerebrovascular accident or stroke, chronic obstructive pulmonary disease, arthritis, and cancer.

Data are presented as mean ± *SD*, *n* (%), or median (IQR).

*One-way ANOVA for normally distributed variables, Kruskal–Wallis ANOVA for non-normally distributed variables, Chi-square for frequencies.

Table 4. Comparing the Overlap Between the Different Trajectories for Each Physical Performance Measure

Comparison	Males			Females		
	Most Unfavorable Trajectories	Most Favorable Trajectories	Total in Similar Trajectory	Most Unfavorable Trajectories	Most Favorable Trajectories	Total in Similar Trajectory
Chair stand vs gait speed	N = 1 (0.6%)	N = 47 (26.4%)	N = 48 (27%)	N = 14 (7.4%)	N = 23 (12.2%)	N = 37 (19.7%)
Chair stand vs handgrip strength	N = 3 (1.7%)	N = 55 (31.3%)	N = 58 (33%)	N = 2 (1.1%)	N = 59 (32.2%)	N = 61 (33.3%)
Gait speed vs handgrip strength	N = 3 (1.6%)	N = 22 (12%)	N = 110 (60.1%)	N = 4 (2.0%)	N = 13 (6.5%)	N = 87 (43.7%)

the chair stand analyses was two, whereas for the gait speed and handgrip strength analyses three distinct trajectories were obtained. Finally, when participants were classified in an unfavorable trajectory in one performance measure, this did not necessarily mean that these participants were also classified in the most unfavorable trajectory of the other physical performance measures: the identified developmental trajectories showed little overlap. This emphasizes the use of multiple measurement methods to assess physical performance in young older adults.

A longitudinal study researching distinct trajectories of physical performance (as measured by the SPPB) in an older adult population with a mean age of 81 years old showed three distinct trajectories: low declining, high declining, and high stable performance. Participants were more likely to be classified in the unfavorable, declining trajectories if they were older, female, showed more depressive symptoms, lower cognitive function, and a higher presence of other comorbid diseases (13). All these measures did not show to be of relevant importance in the younger-old, as we found that baseline performance was the main indicator for belonging to the distinct physical performance trajectories. This was also observed in another population of slightly older well-functioning older adults (12). These results corroborate the findings from a representative cohort study of well-functioning community-dwelling older adults suggesting that current physical performance measures strongly predict the development of mobility and functional disability in the subsequent years, independent of physical performance assessed earlier in time (23). Moreover, even in a population of comparable slightly older well-functioning adults, older age, gender, and the number of comorbidities showed to be determinants for the classification in the more unfavorable trajectories of gait speed (12,21) and handgrip strength (21). In the present study, the trajectories described for gait speed, for example, show that participants with a low gait speed at baseline show a steeper slope of the trajectory. This indicates that once participants are limited in their physical performance as measured by gait speed, the decline in this domain will continue at a faster rate, which might also be the case for other performance measures.

Our participants had a mean gait speed of 0.51–1.18 and 0.69–1.20 m/s over the trajectories for, respectively, males and females at baseline. Population means for healthy individuals have been obtained in a meta-analysis: males aged 60–69 years old had a mean gait speed of 1.33 m/s and females of 1.24 m/s (24). Compared to these population means, we found overall lower mean gait speed values at baseline. However, this could be explained by our method to assess gait speed: relatively short distance of 6 m, including the presence of a turn halfway and thereby upgrading the task in complexity and the chance of lowering measured gait speed (25–27). For example, the LASA study of Schaap and colleagues (27) showed that the prevalence of low gait speed (ie, <0.8 m/s) lowered from 54%

when measured over 3 m to 26% over 6 m. This shows that it is likely that the 3 m assessment method shows rather slower assessments of gait speed. However, as gait speed was used as a continuous measure in our study and no cutoff value to distinguish slow walkers from fast walkers was used in the present analyses, we believe that this measure is still able to describe trajectories of gait speed in this population.

Nevertheless, a direct comparison of the gait speed compared to studies with different assessment methods should be done with caution. On the other hand, it might suggest that other factors already lowered the participants' gait speed, invoking a further negative spiral. Gait speed is often seen as the functional, sixth "vital sign," because of its association with increased disability and mortality in older adults (10,28–30). This corroborates the importance of counteracting a progressive decline in gait speed at an early stage.

The tandem stand test is part of the SPPB measuring balance and was originally developed for community-dwelling older adults aged 70 years and over (17). It is known that the ability to perform a tandem stand for 10 seconds shows ceiling effects in individuals aged 60–70 years, as more than 80% is able to fulfill this task (31). This could explain the relatively little heterogeneity in the trajectory shape of the tandem stand test.

Most participants showed a stable trajectory of the chair stand test. A large study conducted by Hall and colleagues (32) showed age-related physical performance across the age range from 30 to 90+ years old based on data of multiple large-scale population studies. They showed that the number of chair stands in 30 seconds, a fairly comparable measure of the five-repetition sit-to-stand test used in our study, lowered with age showing an age-related discrepancy emerging for the 50–59-year-old cohort. The next decade showed fairly stable performance, subsequently showing a steep decline for the next two decades. Our results are similar to these findings: our obtained stable trajectories may precede the (steeper) decline demonstrated after the ages of 80+ years.

All identified trajectories of handgrip strength show a (gradual) decline over time, without any apparent trajectory of a steep(er) decline. This is in line with a previous study that described three trajectories of handgrip strength with similar slopes in community-dwelling Japanese adults with a slightly older mean age of 71 years old (21). On a population level, this could be explained by the fact that handgrip strength gradually declines with 0.06 kg per year between the ages of 20 and 50 years old. From 50 years onwards, the decline is steeper corresponding to 0.37 kg per year (33). According to this data, no specific transition point in decline in this cohort based on participants aged 60–70 years old could be expected.

We found strikingly little overlap between the different trajectories of physical performance measures. Nogueira and colleagues compared the muscle strength of elbow flexors and knee extensors

between younger and older men in the same level of daily physical activity. They found that elbow flexors muscle strength remained, whereas knee extensor strength was lower in older men when compared to the younger men (34). From these findings we would expect high overlap between gait speed- and chair stand trajectories in particular. However, this was not the case. This might be due to the fact that next to quadriceps strength, also other aspects as physiological and psychological processes influence the sit-to-stand test performance in older adults and that this test is not merely a proxy for lower limb strength (35). Another suggestion for the little overlap could be that there is a different underlying mechanism and timing for decline in the different physical performance measures.

Clinical Implications

Trajectories of physical performance were heterogeneous, but showed similar patterns for males and females. Little overlap between measures was shown, suggesting different mechanisms for decline. This study emphasizes the use of multiple domains to assess physical performance.

Strengths and Limitations

A strength of this study is the long-term data obtained from a large population of the ongoing LASA. This cohort study focuses on determining predictors and consequences of aging and considers different domains, measuring not only physical functioning, but also emotional, cognitive and social functioning in community-dwelling older adults in the Netherlands. By following these participants longitudinally, the change over 9-year time could be studied in detail.

By using contemporary latent class growth models, we identified distinct trajectories of physical performance measures over time. Although latent class growth models moves beyond the idea of summarizing "an" average developmental trajectory for the sample, a point of discussion is the decision of the optimal number of classes; this choice is usually made on the basis of several statistical fit criteria in combination with substantive interpretation. Multiple decisions are to be made during the modeling process and open communication about this process is crucial, yet scarcely reported. Therefore, we reported our choices, syntaxes and results in detail on Open Science Framework (https://osf.io/q2tbw/) to facilitate replicability and increase transparency.

To answer our research questions, we opted for separate models for each of the performance measures. It has been suggested that group-based multitrajectory models, for example explained by Nagin and Odgers (36), could also have answered our research questions. These models examine overlap of people in trajectories across multiple outcomes and would therefore fit the aim of our study. However, we opted for separate models because of several reasons: first, these models are quite computationally challenging when more than two outcomes are modeled simultaneously, second, these analyses estimate the latent class based on combined trajectories of the individual physical performance measures, in a way "forcing" relatively equal heterogeneity in development for each of the performance measures. Prior to this study, the number and characteristics of the classes for the performance measures individually were unknown, and after the individual latent class models were conducted, indeed for some measures the three-class model was the optimal model whereas for others only one or two distinct classes emerged. Third, by analyzing combined trajectories, we actually a-priori assume (similar) degree of overlap between the performance measures which was unknown prior to our study.

Another limitation of the present study is the use of items of the SPPB as physical performance measures in this particular age group. It is known that this measurement method has high ceiling effects, resulting in maximum scores even though actual differences in physical performance are present (31,37). Next to this, the assessment of handgrip strength is currently under debate, as handgrip strength cannot be assumed a proxy for overall muscle strength (38). Future research should focus on introducing knee extension strength as a measure of overall muscle strength (39). Finally, several identified trajectories had a small sample size, challenging elaborate further analyses and complicating generalizability of the obtained trajectories.

Conclusion

The decline in physical performance measured by tandem stand, gait speed, chair stand, and handgrip strength is relatively heterogeneous. The shape of different trajectories was mainly determined by the baseline measure of the physical performance measure itself, instead of clinical characteristics or lifestyle factors. Little overlap between the most favorable and most unfavorable trajectories in both males and females was present when combining all physical performance measures. This suggests different underlying mechanisms responsible for decline in the different measures of physical performance. Multiple measurements methods are needed to assess physical performance in young older adults to detect those who would likely benefit preventive interventions.

Supplementary Material

Supplementary data is available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

Author Contributions

Concept and design: T.H., N.van S., A.M., and M.P. Drafting of this manuscript: T.H., A.R., N.van S., A.M., and M.P. Critical revision of the article for important intellectual content: All members. Final approval of the article: All members.

Conflict of Interest

None reported.

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