Effect of calendar age on physical performance: a comparison of standard clinical measures with instrumented measures in middle-aged to older adults

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Abstract

Background: Decline in physical performance is highly prevalent during ageing. Identification of sensitive markers of age-related changes in physical performance is important for early detection, development of therapeutic strategies and insight into underlying mechanisms. We studied the association of calendar age and familial longevity with standard clinical and instrumented measures of physical performance in a cohort of healthy middle-aged to older adults.

Methods: Cross-sectional analysis within the Leiden Longevity Study consisting of offspring of nonagenarian siblings and their partners (n=300, mean age (SD) 65.3 (6.7) years). Standard clinical measures were 25-meter walking speed and total duration of the chair stand test (CST). Instrumented measures were determined using a body fixed sensor. Dependence of physical performance on calendar age and familial longevity (offspring versus partner status) was analyzed using linear and logistic regression, respectively, adjusted for gender and height.

Results: Higher calendar age was associated with slower walking speed and longer duration of the CST (standardized β (95% CI) -0.024 (-0.042;-0.006) and 0.035 (0.014;0.056), respectively). Instrumented measures showed similar effect sizes with strongest associations for gait stability and symmetry in mediolateral direction and for the extension and flexion phase of sit-to-stand and stand-to-sit transfers, respectively. No differences were observed between offspring of nonagenarian siblings and their partners.

Conclusions: Standard clinical and instrumented measures of physical performance are associated with similar effect size to age-related changes in physical performance observable from middle age. The potential added value of instrumented measures for understanding underlying mechanisms requires further attention.

Introduction

Decline in physical performance is highly prevalent during ageing leading to loss of independence and a poorer quality of life[1]. Furthermore, older adults with impaired physical performance have a high risk of falls, further reducing the quality of life and placing a heavy economic burden on society[2]. Identification of sensitive markers of age-related changes in physical performance is of utmost importance for the early detection, development of therapeutic strategies and insight into underlying mechanisms.

Assessment of physical performance is part of the comprehensive geriatric assessment (CGA) in clinical practice. Important clinical measures of physical performance commonly include walking speed and the duration of repeated sit-to-stand movements, assessed by the chair stand test (CST)[3,4]. Walking speed is an important indicator of health status and function by reflecting the interaction of several underlying systems, such as the central and peripheral nervous, sensory, muscular, skeletal, and cardiopulmonary system[5,6]. Sit-to-stand movements are one of the most mechanically demanding functional tasks during daily activities[7]. Furthermore, the CST is an important indicator for the performance of other daily activities, like climbing stairs, by measuring lower body strength[8].

Standard clinical measures of physical performance, using simply total time as the outcome, provide a common output representing a combination of possible underlying mechanisms. Based on previous studies showing the association of calendar age with various instrumented measures of physical performance and their use in the early identification and prediction of pathology[9-11], instrumented measures might be sensitive markers of age-related changes in physical performance providing possible insights into underlying determinants. Therefore, we assessed the association of calendar age with standard clinical and instrumented measures of the 25-meter walk and CST in a study population of offspring of nonagenarian siblings together with their partners. We used this study population of middle-aged to older adults to be able to assess changes in physical performance that are already observable from middle age in the absence of overt diseases. Additionally, we compared both measures between the offspring of nonagenarian siblings, who are enriched for familial factors of longevity, and their partners to assess the sensitivity for familial longevity representing the biological age of the participants, i.e. the person's rate of ageing compared to their calendar age.

Methods

The Leiden Longevity Study

The Leiden Longevity Study is a longitudinal cohort consisting of 421 families of long-lived Caucasian siblings of Dutch descent[12]. Families were recruited if at least two long-lived siblings were alive and met the age criteria of ≥89 years for males and ≥91 years for

females. Additionally, the offspring of these long-lived families were included together with their partners as controls being of comparable age and sharing the same socioeconomic and geographical background. Enrolment took place between July 2002 and May 2006. Physical performance was assessed among a random subgroup of participants (n=300) between September 2009 and December 2010. All physical performance tests were performed in the Leiden University Medical Center by two research nurses. The Medical Ethical Committee of the Leiden University Medical Center approved the study and written informed consent was obtained from all participants.

Instrumentation

During the 25-meter walk and CST, a body fixed sensor (Dynaport® Hybrid, McRoberts BV, The Hague, The Netherlands) was inserted in an elastic belt and positioned on the lower back at the height of the second lumbar vertebra[13]. The sensor consisted of one triaxial accelerometer and three uniaxial gyroscopes with a sampling rate of 100 Hz. The start and end of each physical performance test was marked by the research nurse using a remote control. Participants wore non-slip socks during all physical performance tests.

25-meter walk

The 25-meter walk was performed twice in steady state over a length of 30 m, i.e. time started at 2.5 m and stopped at 27.5 m. Participants were asked to walk at their preferred speed. Gait characteristics were determined over the time interval of begin till end marker of the test. Walking speed was used as standard clinical measure and determined by dividing the distance of 25 m by the total duration of the test. Instrumented measures of gait performance were determined using a previously developed algorithm, of which the precision, reliability and validity has been shown in earlier studies[14,15]. Because of the relatively short distance of the 25-meter walk for determination of some gait characteristics, like stride-to-stride variability or local dynamic stability[16], we used only those variables with an ICC $\geq$0.80 over two repeated measurements. This resulted in four different gait characteristics, i.e. gait kinematics, stability, symmetry and variability, which were included in the statistical analyses for each participant. Data were aligned to a common, body centered reference frame with axes in the vertical (VT), mediolateral (ML) and anterior-posterior (AP) direction. Thereby the VT direction was defined as the direction of the mean acceleration signal. Stride time was estimated as measure of gait kinematics. The standard deviation of the acceleration signal, defined as the movement intensity which is equivalent to the acceleration root mean square, was used as measure of gait stability. Gait symmetry was estimated by the harmonic ratio. The amplitude of the dominant frequency of the signal's power spectral density within the frequency range of locomotion (0.5 – 3 Hz) was used as measure for consistency and variability of gait. Gait stability, symmetry and variability were determined in VT, ML and AP direction. For each parameter, the mean

of the two measurements was used for analyses. Due to missing data, data was available for 292 subjects (97%) (Figure 1).

Chair stand test

The ability to rise from a chair was tested by the CST. Participants were asked to stand up and sit down five times as quickly as possible from a straight-backed chair with default seat height. Total duration of the CST was used as standard clinical measure and determined by the time between begin and end marker of the test. Repeated sit-to-stand and stand-to-sit transfers were detected automatically by a commercially available algorithm of which the precision, validity and reliability has been shown previously in older adults[11,13,17]. Thereby, four main phases were distinguished; sit-to-stand, standing, sitting and stand-to-sit. The sit-to-stand and stand-to-sit phases were distinguished further into a flexion and extension phase, according to flexion and extension of the lower back. For each repetition, the duration of the different phases was determined as well as the maximum angular velocity (in deg/s) of the flexion and extension phases. For each parameter of the four main phases, mean values of at least four repeated transfers were calculated and used for statistical analyses. Due to technical problems in the automated signal analysis, data on the CST was available for 221 (74%) participants (Figure 1), which was a random loss of participants.

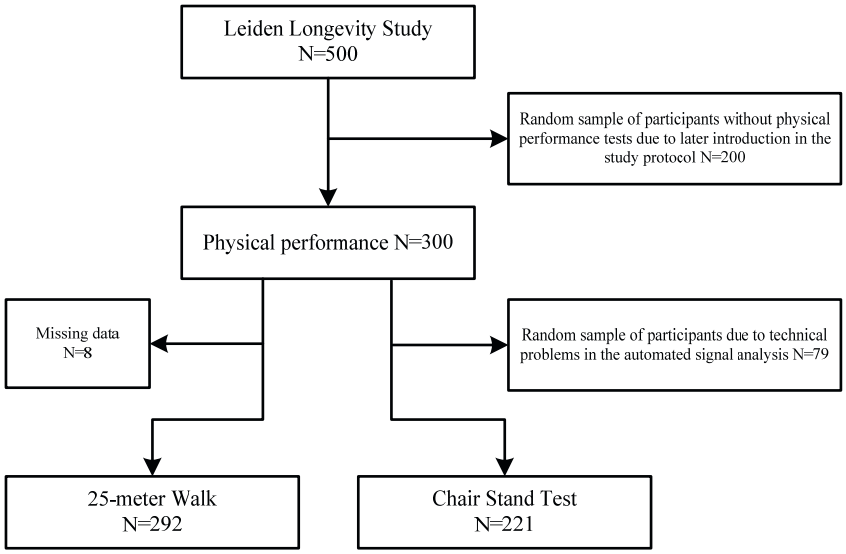

Figure 1 Flow chart of the study population with available data on the different physical performance tests.

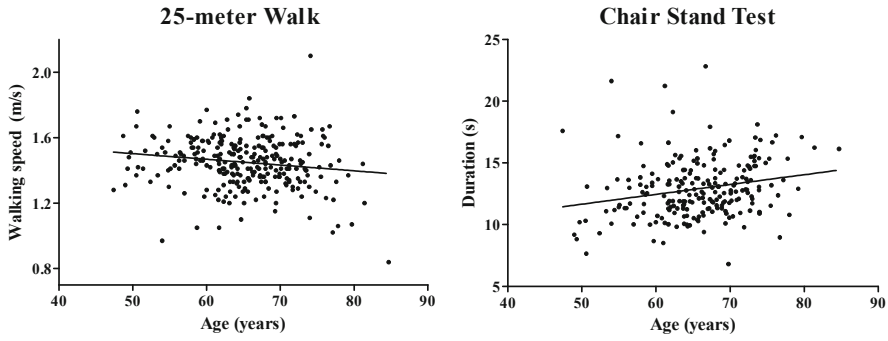

Figure 2 Scatter plots with trend lines of standard clinical measures of the 25-meter walk and chair stand test, i.e. walking speed in meter per seconds (m/s) and duration in seconds (s), respectively, plotted against calendar age in years.

Statistical analysis

Continuous variables with Gaussian distribution are presented as mean and standard deviation, non-Gaussian distributed variables as median and interquartile range, and categorical variables as number and percentage. Linear and logistic regression analysis was used to assess the cross-sectional association between calendar age and physical performance and between familial longevity (offspring versus partner status) and physical performance, respectively. Results were adjusted for gender and height. In the analysis testing differences depending on familial longevity, results were adjusted additionally for calendar age and for familial relationships among the offspring using robust standard errors.

All statistical analyses were performed with the normal values of physical performance (defined as unstandardized) and with the parameters of physical performance expressed as z-scores to enable the comparison of effect sizes. The relation between calendar age and standard clinical measures of physical performance were visualized by using scatter plots. The comparison of effect sizes was visualized by plotting the estimated mean (standard error) of the z-scores of the standard clinical and instrumented measures of the 25-meter walk and CST in tertiles of calendar age. For the instrumented measures of the 25-meter walk and CST, the parameters with the highest effect sizes for each of the gait characteristics, i.e. kinematics, stability, symmetry and variability, and for each phase of the CST were plotted.

P values less than 0.05 were considered statistically significant. All statistical analyses were performed with SPSS version 20.0 (SPSS Inc., Chicago, USA) and Stata version 12.0 (Stata, College Station, USA). Figures were made with GraphPad Prism 5 (GraphPad Software, Inc., La Jolla, USA).

Results

The characteristics of the participants are shown in Table 1 together with the characteristics stratified for offspring and partners. Mean age (SD) of all participants was 65.3 (6.7) years. Offspring and partners had similar calendar age, years of education and measures of anthropometrics. The prevalence of age-related diseases, like diabetes mellitus and hypertension, was lower among offspring compared to their partners. In Figure 2, the 25-meter walking speed and duration of the CST for all participants is plotted against calendar age.

Table 2 presents the association between calendar age and physical performance. Participants with a higher calendar age had a slower walking speed and longer duration of the CST (standardized β (95% CI) -0.024 (-0.042;-0.006) and 0.035 (0.014;0.056), respectively). According to the instrumented measures of gait characteristics, i.e. gait kinematics, stability, symmetry and variability, a higher calendar age was associated with a longer stride time, lower movement intensity and harmonic ratio in ML and AP direction and a higher amplitude of the dominant frequency in VT direction. During the sit-to-stand phase of the CST, a higher calendar age was associated with a longer duration and slower

Table 1 Characteristics of all participants and stratified by offspring of nonagenarian siblings and their partners.

	All (N=300)	Offspring (N=151)	Partners (N=149)
Demographics			
Females, n (%)	152 (50.7)	71 (47.0)	81 (54.4)
Age, years	65.3 (6.7)	65.7 (6.1)	65.0 (7.3)
Education, years*	12 (10 - 15)	12 (10 - 15)	12 (10 - 15)
Anthropometrics			
Height, cm	172.4 (8.5)	172.4 (8.8)	172.4 (8.2)
Weight, kg	79.3 (14.1)	78.5 (13.9)	80.1 (14.2)
Comorbidities			
Diabetes Mellitus	18 (6.8)	4 (3.0)	14 (10.6)
Myocardial infarction	8 (3.0)	3 (2.2)	5 (3.7)
Stroke	8 (2.9)	3 (2.2)	5 (3.7)
Hypertension	73 (27.1)	32 (23.4)	41 (31.1)
COPD	9 (3.3)	5 (3.6)	4 (3.0)
Malignancy	17 (6.3)	7 (5.1)	10 (7.6)
Rheumatoid arthritis	4 (1.5)	2 (1.5)	2 (1.5)
Intoxications			
Users of alcohol†	237 (79.3)	116 (77.3)	121 (81.2)
Former and/or current smokers	203 (67.9)	94 (62.7)	109 (73.2)

Values are expressed as mean (standard deviation), unless otherwise indicated. Abbreviations: n, number; COPD, Chronic Obstructive Pulmonary Disease. *Values are expressed as median (interquartile range). †Using ≥1 units per week.

Table 2 Physical performance dependent on calendar age in years presented unstandardized and expressed as z-score.

		Unstandardized		Expressed as z-score		
	All subjects	**β**	**95% CI**	**β**	**95% CI**	**p**
25-meter Walk‡						
Standard measure						
Walking speed, m/s	1.45 (.009)	-.004	-.007;-.001	-.024	-.042;-.006	.008
Gait kinematics						
Stride time, s	.98 (.004)	.001	.000;.002	.017	.001;.033	.041
Gait stability						
Movement intensity VT, m/s^2	3.13 (.040)	-.012	-.024;.000	-.017	-.035;.000	.057
Movement intensity ML, m/s^2	2.15 (.034)	-.016	-.025;-.006	-.027	-.044;-.011	.001
Movement intensity AP, m/s^2	2.08 (.027)	-.010	-.018;-.002	-.022	-.040;-.005	.013
Gait symmetry						
Harmonic ratio VT	3.58 (.052)	-.009	-.024;.007	-.010	-.027;.008	.28
Harmonic ratio ML	2.83 (.043)	-.020	-.032;-.008	-.027	-.043;-.010	.002
Harmonic ratio AP	3.12 (.044)	-.014	-.028;-.001	-.019	-.037;-.002	.034
Gait variability						
Ampl. dominant freq. VT, psd	1.37 (.020)	.009	.003;.015	.026	.008;.044	.004
Ampl. dominant freq. ML, psd	.77 (.018)	.001	-.004;.006	.003	-.012;.019	.66
Ampl. dominant freq. AP, psd	.87 (.015)	.002	-.002;.007	.009	-.009;.026	.33
Chair Stand Test†						
Standard measure						
Duration chair stand test, s	12.9 (.16)	.083	.034;.13	.035	.014;.056	.001
Sit-to-stand						
Flexion duration, s	.61 (.01)	.002	.000;.004	.019	-.002;.040	.071
Extension duration, s	.55 (.01)	.005	.003;.007	.045	.024;.065	<.001
Flexion max. angular vel., °/s	172.3 (2.4)	-.70	-1.47;.06	-.020	-.041;.002	.071
Extension max. angular vel., °/s	59.9 (1.5)	-.57	-1.04;-.11	-.025	-.046;-.005	.016
Standing						
Duration, s	.10 (.007)	.003	.000;.005	.024	.003;.045	.022
Sitting						
Duration, s	.39 (.02)	-.001	-.006;.005	-.003	-.025;.018	.75
Stand-to-sit						
Flexion duration, s	.58 (.01)	.006	.003;.009	.043	.022;.063	<.001
Extension duration, s	.72 (.009)	.002	.000;.005	.019	-.002;.039	.075
Flexion max. angular vel., °/s	84.4 (1.6)	-.95	-1.42;-.48	-.041	-.061;-.021	<.001
Extension max. angular vel., °/s	141.4 (2.8)	-1.19	-2.03;-.34	-.029	-.050;-.008	.006

Abbreviations: n=number; β, estimate; CI, confidence interval; p, p-value; VT, vertical; ML, mediolateral; AP, anterior-posterior; ampl., amplitude; freq., frequency; max., maximum; vel., velocity; psd, power spectral density. Associations were assessed by linear regression and adjusted for gender and height. Unstandardized effect sizes and effect sizes with the physical performance parameters expressed as z-scores are given.*Values are expressed as mean (standard error). ‡Data available in n=292 and †n=221 participants.

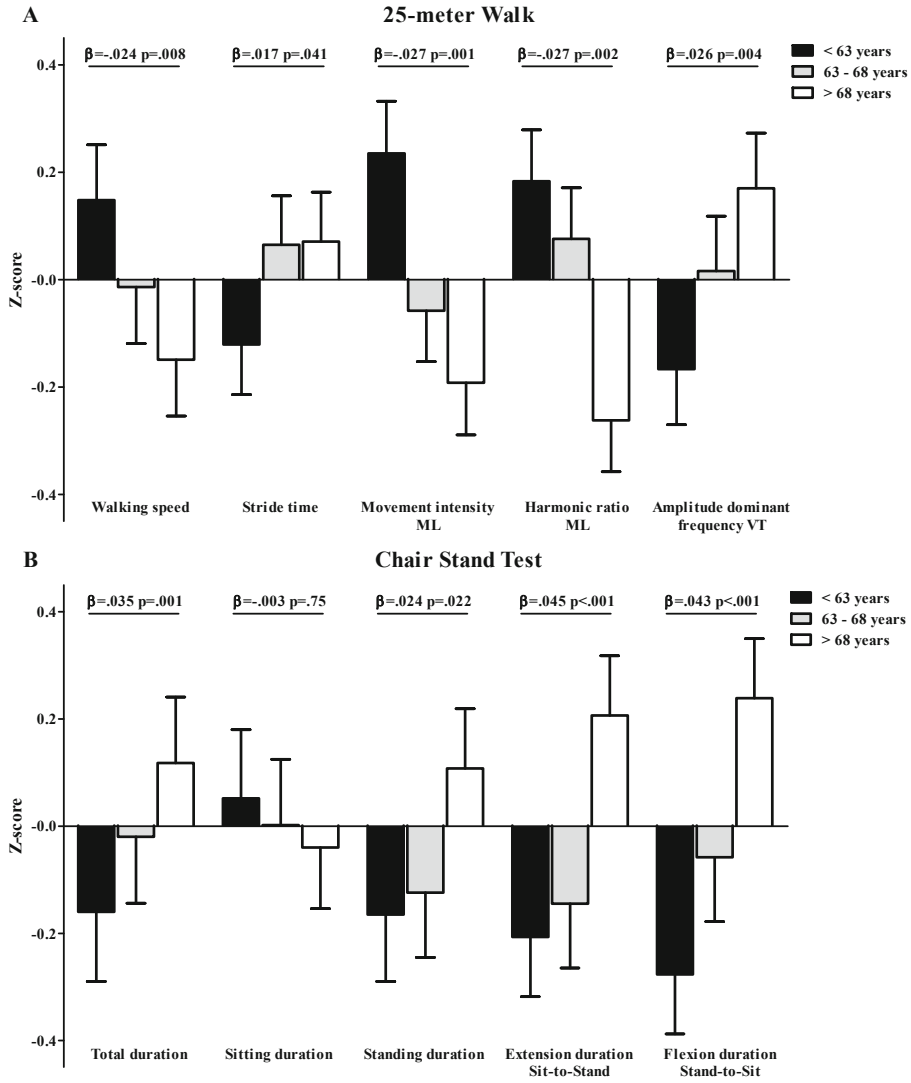

Figure 3 Association of calendar age with standard clinical measures and instrumented measures of the 25-meter walk (A) and chair stand test (B). Estimated mean values expressed as z-scores are given in tertiles of calendar age. Error bars indicate standard error. Standard clinical measures are represented by walking speed and the total duration of the CST. Results are adjusted for gender and height. P-values indicate p for trend. Abbreviations: β, estimate; ML, mediolateral; VT, vertical.

maximum angular velocity of the extension phase. During the stand-to-sit phase, a higher calendar age was associated with a longer duration of the flexion phase and a slower maximum angular velocity of the flexion and extension phase. According to the sitting and standing phase, a higher calendar age was associated with a longer standing duration.

Supplementary Table 1 shows the association of familial longevity with physical performance comparing offspring of nonagenarian siblings with their partners. No statistically significant difference was found between offspring and partners, except for the amplitude in the dominant frequency in AP direction.

In Figure 3, the estimated mean values of the standard clinical and instrumented measures of the 25-meter walk (Figure 3A) and CST (Figure 3B) expressed as z-scores are presented in tertiles of calendar age. Similar effect sizes are shown for walking speed, used as standard clinical measure, movement intensity and the harmonic ratio in ML direction and the amplitude of the dominant frequency in VT direction. According to the CST, the effect sizes of the total duration of the CST as standard clinical measure and the extension and flexion duration of the sit-to-stand and stand-to-sit transfer, respectively, were similar.

Discussion

In this study population of middle-aged to older adults, physical performance assessed with the 25-meter walk and CST was lower at higher calendar age. The effect size for the standard clinical measures dependent on calendar age was similar to those of instrumented measures assessed with a body fixed sensor at the lower back. No statistically significant association was found between familial longevity and both standard clinical and instrumented measures of physical performance, comparing offspring of nonagenarian siblings with their partners.

The association of calendar age with instrumented measures of the 25-meter walk was found in the four different gait domains that were measured, i.e. gait kinematics, stability, symmetry and variability. At higher calendar age, participants had a longer stride time and a lower movement intensity, i.e. a lower magnitude of the trunk acceleration, and less symmetrical gait pattern in ML and AP direction. This is in concordance with earlier findings in healthy older adults[18-20] as well as in older adults with Parkinson's Disease[20] or dementia[19]. Because movement intensity is positively associated with walking speed[21], the lower movement intensity might indicate that participants at higher age adapt their walking speed to remain a stable gait pattern. However, it is only possible to speculate about the order of changes in gait characteristics because the measurements were performed at the participant's preferred speed and not at a fixed walking speed. The associations of gait stability and symmetry with calendar age were strongest in the ML direction, which is the direction that is in general strongly related to the ability to control balance and falls[22,23].

Furthermore, participants with a higher calendar age had a more consistent and less variable gait pattern in VT direction, as was quantified by a higher amplitude of the dominant frequency of the signal's power spectral density. So, additionally to walking speed the assessment of instrumented measures enhanced our understanding of changes in gait characteristics with calendar age.

According to the instrumented measures of the CST, participants with a higher calendar age had in general longer durations and slower angular velocities in the different phases. This is in concordance with a previous study in a small sample of healthy young subjects and older adults recruited from a residential care home[24]. The strongest association with calendar age was found for the extension duration during the sit-to-stand phase and the flexion duration during the stand-to-sit phase. These phases represent the dynamic transitions during the CST[7]. The extension phase during the sit-to-stand phase represents the dynamic transition from a three-point stable support to a two-point stable support. The flexion phase during the stand-to-sit phase represents the dynamic transition in the other direction, from a two-point stable support to a three-point stable support. The necessity of a good balance control and the power to shift the center of mass of the trunk within the base of support in these dynamic transitions might explain the stronger association with calendar age compared to the other phases of the CST.

The instrumented measures of the 25-meter walk and CST assessed in this study show similar effect sizes to changes in calendar age as the standard clinical measures, i.e. walking speed and total duration of the CST. These results indicate that both standard clinical and instrumented measures can be used for the detection of age-related changes in physical performance from middle age. The association of calendar age with specific instrumented measures of the 25-meter walk and CST in this study, i.e. gait stability and symmetry especially in the ML direction and the dynamic transition phase of the CST, enhanced our understanding of possible underlying mechanisms. Additionally to the standard clinical measures, addressing physical performance as a common output representing a combination of underlying systems, the instrumented measures indicated that especially a good balance control is an important determinant for the performance on both tasks. Future studies are needed to further investigate the potential added value of instrumented measures of balance control in the identification of sensitive markers for age-related changes in physical performance and understanding of underlying mechanisms. Finally, this might lead to the possibility to characterize different groups of individuals based on deterioration of specific underlying systems, like deterioration of the sensory system (including vision and the vestibular and proprioceptive system), low muscle mass or strength or cognitive impairment[6], and development of interventions tailored to individual needs.

No differences in performance on the 25-meter walk and CST were found between offspring of nonagenarian siblings and their partners as controls. Unless a significant

decline in physical performance during ageing, familial longevity as strong indicator of healthy ageing is not marked by a better physical performance at middle age. Besides the relatively young age of the participants, the shared environmental conditions of the offspring and partners might be an explanation leading to similar levels of daily physical activity in both groups by performing the activities together. This is supported by previous findings, showing no difference between offspring and partners among other major indicators of lifestyle like body mass index, current smoking and level of education[25]. Furthermore, these results indicate that the younger biological age of the offspring compared to their partners, based on the lower prevalence of age-related diseases[12,25], better cognitive performance[26], preserved insulin sensitivity[27] and fewer senescent cells[28] cannot be detected by physical performance at middle age.

One of the strengths of this study is the study population consisting of middle-aged to older adults with a relatively good health status. This enhanced our insight into sensitive markers for age-related changes in physical performance already observable from middle age and without the presence of overt diseases. Furthermore, the inclusion of offspring of nonagenarian siblings and their partners made it possible to study whether standard clinical and instrumented measures of physical performance are sensitive to familial longevity. The assessment of different physical performance tests and the use of a body fixed sensor made it possible to assess the potential added value of instrumented measures in assessing age-related changes in physical performance from middle age and to enhance our insight into possible underlying mechanisms. Future studies including a wider age range and specific patient populations with repeated measures taken over time are needed to further investigate this. A limitation is the availability of the CST in only 74% of the participants due to technical problems. However, missing data were randomly distributed. The distance of the walk trajectory is both a strength and a limitation. The distance of 25 m enabled the reliable assessment of instrumented measures of gait characteristics additional to walking speed. However, a longer distance or a higher number of strides is needed for the determination of gait characteristics like local dynamic stability and stride-to-stride variability measures[16]. These parameters have been shown to be associated with calendar age and to be important predictors of falls[15,29,30] suggesting that they might be important parameters in the detection of age-related changes in physical performance as well.

In conclusion, standard clinical and instrumented measures of physical performance are associated with similar effect sizes to age-related changes in physical performance in middle-aged to older adults. The assessment of instrumented measures needs further investigation to be able to distinguish different groups of individuals to ultimately tailor interventions to individual needs.

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Supplementary material

Supplementary Table 1 Physical performance dependent on familial longevity (offspring versus partner status[*]) presented unstandardized and expressed as z-score.

			Unstandardized		Expressed as z-score		
	Offspring[§]	Partners[§]	β	95% CI	β	95% CI	p
25-meter Walk[‡]							
Standard measure							
Walking speed, m/s	1.45 (.01)	1.45 (.01)	-.002	-.038;.035	-.011	-.24;.22	.93
Gait kinematics							
Stride time, s	.98 (.01)	.98 (.01)	-.005	-.019;.008	-.081	-.29;.13	.45
Gait stability							
Movement intensity VT, m/s^2	3.12 (.06)	3.14 (.05)	.015	-.13;.16	.022	-.20;.24	.84
Movement intensity ML, m/s^2	2.15 (.04)	2.16 (.05)	-.015	-.14;.11	-.025	-.24;.19	.82
Movement intensity AP, m/s^2	2.08 (.04)	2.07 (.04)	-.007	-.11;.093	-.016	-.24;20	.89
Gait symmetry							
Harmonic ratio VT	3.50 (.07)	3.67 (.07)	.15	-.053;.36	.17	-.059;.41	.14
Harmonic ratio ML	2.84 (.06)	2.82 (.06)	-.056	-.22;.11	-.075	-.30;.15	.51
Harmonic ratio AP	3.13 (.06)	3.11 (.07)	-.030	-.21;.15	-.040	-.28;.20	.75
Gait variability							
Ampl. dominant freq. VT, psd	1.34 (.03)	1.40 (.03)	.070	-.010;.15	.21	-.031;.45	.088
Ampl. dominant freq. ML, psd	.77 (.03)	.77 (.02)	-.029	-.091;.034	-.095	-.30;.11	.37
Ampl. dominant freq. AP, psd	.91 (.02)	.84 (.02)	-.072	-.13;-.015	-.28	-.50;-.059	.013
Chair Stand Test[†]							
Standard measure							
Duration chair stand test, s	12.8 (.22)	13.0 (.23)	.30	-.30;.91	.12	-.13;.38	.33
Sit-to-stand							
Flexion duration, s	.61 (.01)	.62 (.01)	.002	-.024;.028	.018	-.26;.29	.90
Extension duration, s	.55 (.01)	.55 (.01)	.002	-.025;.030	.023	-.24;.29	.86
Flexion max. ang. vel., °/s	169.9 (3.5)	174.9 (3.3)	4.16	-5.50;13.8	.12	-.15;.38	.40
Extension max. ang. vel., °/s	58.6 (2.0)	61.3 (2.4)	.93	-4.95;6.81	.041	-.22;.30	.76
Standing							
Duration, s	.10 (.01)	.10 (.01)	.003	-.025;.031	.024	-.23;.28	.85
Sitting							
Duration, s	.37 (.02)	.40 (.03)	.038	-.032;.11	.15	-.12;.42	.29
Stand-to-sit							
Flexion duration, s	.57 (.01)	.58 (.01)	.016	-.019;.052	.11	-.14;.36	.37
Extension duration, s	.72 (.01)	.71 (.01)	-.002	-.036;.032	-.016	-.28;.25	.90
Flexion max. ang. vel., °/s	85.6 (2.2)	83.1 (2.2)	-4.65	-10.7;1.39	-.20	-.46;.06	.13
Extension max. ang. vel., °/s	142.1 (3.8)	140.7 (4.0)	-3.70	-14.7;7.28	-.091	-.36;.18	.51

Abbreviations: n=number; β, estimate; CI, confidence interval; p, p-value; VT, vertical; ML, mediolateral; AP, anterior-posterior; ampl., amplitude; freq., frequency; max., maximum; ang., angular; vel., velocity; psd, power spectral density. Associations were assessed by logistic regression and adjusted for calendar age, gender and height. Robust standard errors were used to account for familial relationships among the offspring. Unstandardized effect sizes and effect sizes with the physical performance parameters expressed as z-scores are given. [*]Offspring = 0, partner = 1. [§]Values are expressed as mean (standard error). [‡]Data available in n=148 offspring and n=144 partners and in [†]n=114 offspring and n=107 partners.

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