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PHYSICAL FUNCTION AND HISTORY OF FALLS:

Results from the “Invecchiamento e Longevità nel Sirente (*i/SIRENTE*)” Study

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Abstract

Background and Aims—Falls are a common cause of morbidity and mortality in the elderly, but the consequences of falls on physical function measures are still unclear. The present study explores the association between history of falls and physical function measures in older persons.

Methods—Data are from baseline evaluation of the *i/SIRENTE* study. Physical performance was assessed using the Short Physical Performance Battery (SPPB) and the 4-m walking test. Muscle strength was measured by hand grip strength. Functional status was assessed using the Basic and Instrumental Activities of Daily Living (ADLs and IADLs, respectively) scales. Self reported history of falls occurred during the previous 90 days was recorded. Analyses of covariance and linear regression models were performed to evaluate the relationship between history of falls and physical function measures.

Results—Mean age of participants (n=364) was 85.9 (SD=4.9) years. Fifty participants (15.9%) reported at least one fall event in the previous 90 days. Participants with history of falls had significantly lower adjusted means for the 4-m walking test (0.382 m/s) and the SPPB score (5.602) compared to non fallers (0.498 m/s and 6.780, respectively, all $p < 0.05$). No statistically significant association of hand grip strength, ADLs and IADLs scales with history of falls was reported after adjustment. Physical activity was the strongest confounder of the association between history of falls and physical function. Physically active participants had a significantly higher physical function compared to sedentary subjects, regardless of history of falls.

Conclusions—Physical performance measures, walking speed and SPPB in particular, are negatively associated with history of falls.

INTRODUCTION

Falls are a common event in older adults and are associated with increased morbidity and disability¹. The prevalence of falls in older community dwelling populations is approximately 30%² and the rate increases to 40% among the “oldest-old”³. Moreover, older persons have a high susceptibility to fall-related injuries⁴. In fact, in the elderly, two-thirds of the death from unintentional injuries are related to a fall event⁵. Fall-related medical

conditions represent an important portion of the total health expenditure for persons aged 65 and older in the United States, resulting in direct medical costs of 6 to 8 billion dollars per year⁶.

Since the last decades, functional assessments have been introducing in clinical and research settings. They represent multidimensional instruments aimed to better address the complexity of older persons' health status and to focus on their level of functioning and independence⁷. Moreover, they have shown to be predictors of major health related outcomes and useful tools to follow clinical changes over time.

A large number of physical function measures have been developed and used over the years. These instruments vary on their objectives and information able to provide. Basic and Instrumental Activities of Daily living (ADLs and IADLs, respectively) represent two of the most common measures of physical function designed to estimate physical limitations in older adults. They have also shown to be predictive of mortality⁸. Physical performance measures (such as walking speed and Short Physical performance Battery, SPPB) and muscle strength assessment (usually measured as hand grip strength) are objective and standardized instruments designed to assess an individual's overall and muscular functioning, respectively. Similarly, they have shown to predict major health related events in older persons, like physical disability^{9;10} and death^{11;12}. However, to our knowledge, no study has yet compared which of these physical function measures is more affected by the history of falls, a major and traumatic event in the life of elders.

We used baseline data from the "Invecchiamento e Longevità nel Sirente" (Aging and longevity in the Sirente geographic area, *iSIRENTE* Study) study to observe the relationship of history of falls with physical performance and functional measures. Moreover, we evaluated which of the tested measures is most strongly associated with history of falls.

METHODS

For the present analyses, we used baseline data from the *iSIRENTE* Study. *iSIRENTE* is a prospective cohort study performed in the mountain community living in the Sirente geographic area (L'Aquila, Italy) and developed by the teaching nursing home Opera Santa Maria della Pace (Fontecchio, L'Aquila, Italy) in a partnership with local administrators and primary care physicians. Details of the design and methods of *iSIRENTE* have been described elsewhere¹³. Briefly, potential study participants were identified by selecting from the Registry Offices every person born before 1st January 1924 and still living in the municipalities involved in the study at the end of October 2003. A total number of 364 participants were enrolled in the study. The Catholic University of Sacred Heart (Rome, Italy) ethical committee ratified the entire study protocol. All the participants signed an informed consent at the baseline visit.

Participants' baseline assessments began in December 2003 and were completed in September 2004. Clinical interview and functional assessment were performed at the study clinics located in each town. Home visit was performed if participant was unable to reach

the study clinic. Information was obtained by the participant or, if he/she was incapable, by a proxy.

The Minimum Data Set for Home Care (MDS-HC)

The Minimum Data Set for Home Care (MDS-HC) instrument¹⁴ was administered to all the study participants. The MDS-HC contains a variety of different, multi-item summary scales, exploring socio-demographics, cognitive [using the Cognitive performance Scale (CPS)¹⁵] and physical status variables as well as major clinical diagnoses. Besides, the MDS-HC includes information about an extensive array of signs, symptoms, syndromes, and treatments. The MDS items have shown an excellent inter-rater and test-retest reliability when completed by nurses performing usual assessment duties (average weighted Kappa=0.8)^{15;16}. A questionnaire shared with the 'Invecchiare in Chianti (inCHIANTI) study¹⁷ was also administered, which explores family history, lifestyle, nutrition, physical activity and other behavioral factors.

History of falls

Participants (or proxy) were asked to report any fall event they had experienced during the previous 90 days. A fall event was defined by a sudden loss of gait causing the hitting of any part of the body to the floor.

Physical function assessment

Physical performance measures—Physical performance was assessed by the 4-meter walking test and the SPPB score. This latter measure is composed of three timed tests: walking speed, balance, and chair stand tests^{9;18}. Timed results from each test were rescored from 0 (worst performers) to 4 (best performers). For the present analyses we will use the total score (ranging from 0 to 12) resulting from the sum of the three separate tests.

Results from walking speed and chair stand tests were categorized on the basis of the iLSIRENTE population-specific quartiles, as described below¹⁹. Such categorization was not applicable to the balance test results, given the high percentage of subjects (more than 50%) successfully completing this task. Therefore, we categorized the balance test results according to previously established cut-points provided by Guralnik et al.^{9;18}.

Walking speed was evaluated measuring the participants' gait speed (in m/sec) at their usual pace, over a 4-meter course. The following cut-points (based on sample population quartiles) for gait speed were used to categorize the variable: 0.38 m/s, a score of 1; 0.39 to 0.57 m/s, a score of 2; 0.58 to 0.76 m/s, a score of 3; 0.77 m/s, a score of 4. Participants unable to complete the task were scored 0.

To assess the chair stand test, participants were asked to stand up from a chair with their arms folded across the chest five times in a row as quickly as possible. The time needed to complete the task was recorded. Quartiles for the length of the time required for this measure were used for scoring as follows: 17.0 seconds, a score of 1; 14.1 to 16.9 seconds, a score of 2; 11.9 to 14.0 seconds, a score of 3; and 11.8 seconds, a score of 4. Subjects unable to complete the test received a score of 0.

To assess the balance test, participants were asked to perform three increasingly challenging standing positions: side-by-side position, semi-tandem position, and tandem position. Participants were asked to hold each position for 10 seconds. Participants unable to hold a side by side position for 10 seconds were scored 0 and no further evaluated on balance tasks. Participants were scored as 1 if they were able to hold a side-by-side standing position for 10 seconds, but were unable to hold a semi-tandem position for 10 seconds; a score of 2 if they were able to hold a semi-tandem position for 10 seconds, but were unable to hold a tandem position for more than 2 seconds; a score of 3 if they were able to stand in tandem position for 3 to 9 seconds; and a score of 4 if they were able to hold the tandem position for 10 seconds^{9;18}.

Muscle strength measure—Hand grip strength, measured by a hand held dynamometer, was used to assess muscle strength. Participants were asked to perform the task twice with each hand. The average of the best results obtained at each side was used for the present analyses.

Functional status measures—ADLs and IADLs scales were assessed using the MDS-HC instrument¹⁵. ADLs scale (range 0-7, higher number indicates higher impairment) explores the ability to perform the following tasks: eating, dressing, personal hygiene, mobility in bed, dressing, transferring (from/to bed, chair or stand position) and use of the toilet. IADLs scale (range 0-7, higher number indicates higher impairment) included: meal preparation, shopping, telephone use, housekeeping, responsibility for medication intake, handling finances and use of transportation.

Covariates

Covariates included sociodemographic factors (age, gender, marital status, social network and smoking habit), health indicators (body mass index, cognitive performance, and biological markers), physical activity and comorbidity.

Body Mass Index (BMI)—Body weight was measured with light clothes using a calibrated bathroom scale. Body height was measured using a standard stadiometer. BMI was defined as weight in kilograms divided by the square of height in meters.

Biological markers—At baseline assessment, 20-40 mL of peripheral blood were collected from all the study participants after an overnight fast and delivered to a local laboratory. Standard determinations of serum albumin and total cholesterol were performed by commercially available kits suitable on Olympus 2700 (Olympus, Tokyo, Japan) instrumentation.

Physical activity—Physical activity was assessed by asking the participant to provide data on past and current activities involving energy expenditure, including recreational and work-related ones. For the present analyses, we considered as physically active those participants reporting light intensity activities (e.g. walking, dancing, fishing...) performed for at least 2-4 hours per week during the last year.

Comorbidity and number of medications—The following clinical diagnoses were assessed by a study physician on the basis of self- (or proxy-) reported history and clinical record review: coronary heart disease, cerebrovascular disease, congestive heart failure, peripheral artery disease, hypertension, lung disease, osteoarthritis, diabetes, dementia, Parkinson's disease, cancer, depression, vision and hearing impairments. Primary care physicians collected information on up to 18 different drugs received by each patient in the 7 days preceding the assessment. Drugs were coded using the Anatomical Therapeutic and Chemical (ATC) codes²⁰.

Statistical analysis

Descriptive analyses were performed using χ^2 or t-test statistics. Unadjusted and adjusted analyses of covariance were performed to estimate the means of the physical performance, muscle strength and functional status measures, according to the history of falls. Linear regression models were performed adding covariates in a stepwise fashion, to evaluate which was the strongest confounding variable able to modify the strength of all tested associations. Adjustments were made for age, gender and covariates showing an association ($p < 0.1$) with history of falls. A $p < 0.05$ was chosen for statistical significance. All analyses were performed using SPSS software (version 13.0, SPSS Inc., Chicago, IL).

RESULTS

Main characteristics of the study sample are shown in Table 1. Among the 364 persons enrolled in the study, 50 (15.9%) participants reported at least one fall occurred in the 90 days preceding the assessment. Female participants were more likely to have experienced a fall. Physical inactivity, number of medications and diagnoses of depression and hypertension were significantly associated with history of falls. No significant age difference between participants with and without history of falls was reported.

Unadjusted and adjusted means of physical function measures are presented in Table 2, according to the history of falls. In the unadjusted model, all the physical performance, muscle strength and functional measures showed significant and negative associations with history of falls. However, after adjusting for confounding variables, only the 4-meters walking test and the SPPB were strongly and negatively associated with history of falls. ADLs scale showed a border-line significant association with history of falls. No significant gender interaction between physical function measures and history of falls was reported (all p values for interaction terms > 0.2).

Linear regression models, performed adding covariates in a stepwise fashion, showed that physical activity was the strongest confounding variable able to modify the strength of all the tested associations. Therefore, we further investigated the role of physical activity in the association between history of falls and physical function measures. To analyze this relationship, we divided our population in 4 groups according to physical activity level and history of falls. Results of the adjusted analyses of covariance are shown in Figure 1. Active, non fallers, participants had a mean walking speed of 0.645 m/s (95%CI 0.611-0.679 m/s), while sedentary, non fallers, participants had a mean speed of 0.287 m/s (95%CI 0.244-0.330 m/s). Among fallers, active participants had a mean speed of 0.402 m/s (95%CI

0.301-0.504 m/s) and sedentary ones had a speed of 0.262 m/s (95%CI 0.181-0.343 m/s). The walking speed of the active non faller participants was significantly higher than the speed of all the other groups (all p values<0.01). Physically active participants who reported history of falls performed significantly better in the 4-meters walking test than inactive participants without history of falls (p=0.03). No significant difference was found between the walking speed of sedentary participants, regardless of the history of falls (p=0.60). The 4-meters walking test was the variable more affected by history of falls and physical activity; however, consistent findings were obtained for all the other measures of physical function.

DISCUSSION

This is the first study to analyze the relationship between history of falls and physical function measures and to investigate the role of physical activity in this relationship. Moreover, our sample is composed by subjects in an age group often excluded from study participation²¹ but increasingly present in Western societies²².

Our results show that physical function measures are negatively associated with history of falls. In particular, the walking speed and SPPB score were significantly reduced in participants reporting previous fall events. Participants involved in regular physical activity performed better in all the tested physical function measures compared to sedentary subjects, regardless of their history of falls.

Our findings show that physical performance tests are able to capture the history of falls among older persons better than muscle strength or functional status measures. This finding reinforces the role of physical performance measures in the assessment of elderly subjects. In recent years, the number of tools for the evaluation of older people has been rapidly increasing. Each of them provides different information about the health status of the tested subject. However, given the limited time during which assessments can be administered in the every day clinical life, it is important to find a simple, quick and inexpensive instrument able to provide the widest range of possible information.

Performance measures are very informative instruments because they are able to provide a multidimensional, objective and standardized overview of the health status of the elders. These characteristics lack in the hand grip test, which provides an evaluation limited to the individual muscular functioning. BADLs and IADLs scales give important information about a subject's ability to interact with the environment and to live independently. They are also predictors of major health related events such as mortality⁸ and hospitalization²³. On the other hand, they are based on questionnaires and the subjective evaluation of an assessor. Moreover, unlike performance measures, they are not able to detect a preclinical level of disability²⁴.

In our study, walking speed showed the strongest association with history of falls. Previous evidence has shown that this test is a predictor of physical disability as good as the whole SPPB¹⁸. A recent study considering a large sample of well functioning older persons, has shown that a gait speed slower than 1 m/s (in a 6-meters track) is able to distinguish older

persons at high risk of adverse health outcomes²⁵. This finding, combined with results from the present paper, may suggest and promote the routine use of walking speed as a screening instrument of physical function in older persons.

In our study, physical activity is associated with better physical function, independently of history of falls. The increased risk of fall-related injuries in the elderly might be due to the higher comorbidity and the concurrent decline in physiological responses to environmental hazards⁴. Physical activity has shown to reduce the occurrence of a hip fracture after a fall not only by its effect on bone density and bone loss^{26;27} but also through the reduction of the force of impact and the improvement of strength, flexibility, balance, and reaction time²⁷. Moreover, physical activity has been shown to prevent or delay the onset of disability²⁸. Several mechanisms are involved in this result. A not exhaustive list comprehend reduction in fat mass^{29;30} and in level of inflammatory markers^{31;32}, and improvement in depression³³. Our results may also suggest that physical activity might help in preserving physical function after a fall event. This suggestion, even though it needs to be supported by future studies, might encourage physician to promote an active life style among elders.

The prevalence of falls in our population was lower than what previously reported in other studies conducted in community dwelling subjects^{2;34;35}. However, this might be explained by the fact that we collected information about fall events occurred during the 90 days preceding the assessment, while previous papers reported data on falls collected over a larger follow-up. ^{2;34;35}.

Some limitations of our study must be acknowledged. Its cross sectional design does not allow a clarification of the cause-effect mechanism behind the association between history of falls and physical function measures. However, trying to address this limitation, all the analyses took into account several potential confounders of the relationship between falls and physical function. Secondly, we may have missed falls that participants did not recall, a risk that is documented in literature³⁶. Moreover, no information about the causes of falls were collected, so we may have included events related to clinical conditions (such as syncope or stroke), generally excluded from trials on falls². Finally, giving the small number of participants reporting more than one fall, we have not been able to perform separate analyses on “frequent fallers”.

In conclusion, physical performance measures are strongly and negatively associated with fall events. This finding confirms that physical performance tests provide an extensive and multidimensional evaluation of the health status in the elderly and suggests that they are able to better perceive the possible consequences of falls than other functional measures. A wider use of these instruments in clinical and research settings is strongly recommended to improve the assessment of older persons. Regular physical activity may help in the maintenance of physical function independently of the history of falls. Giving the wide spectrum of beneficial effects of physical activity, an active life style should be encouraged among older persons.

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Figure 1.

Adjusted* analyses of covariance between physical function measures (dependent variables), physical activity and history of falls occurred during the last 90 days. The Short Physical Performance Battery score (composed by usual gait speed, balance, and chair stand tests) ranges from 0 (worse performance) to 12 (best performance). ADL: Activities of Daily Living (range 0-7, a higher number indicates higher impairment). IADL: Instrumental Activities of Daily Living (range 0-7, a higher number indicates higher impairment)

*Adjusted for age, gender, physical activity, hypertension, osteoarthritis, diabetes, depression, number of medications

† p<0.05 compared to active non fallers
‡ p<0.05 compared to sedentary non fallers
§ p<0.05 compared to active fallers

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Table 1

Main characteristics (mean±SD, or percentage) of the sample population according to history of falls.

	Total (n=364)	No fall event (n=314)	Fall event (n=50)	p
<i>Socio-demographic characteristics</i>				
Age (years)	85.9 ± 4.9	85.9 ± 5.0	85.6 ± 4.4	0.71
Gender (Female)	67.0	65.3	78.0	0.08
Marital status				
Married	27.7	28.0	26.0	
Widowed	61.8	62.1	60.0	
Never married	10.4	9.9	14.0	
Current smoking	2.2	2.5	-	0.25
Cognitive Performance Scale *	1.1 ± 1.8	1.0 ± 1.8	1.4 ± 1.8	0.22
Body Mass Index (kg/m ²)	25.6 ± 4.5	25.6 ± 4.4	26.1 ± 5.5	0.42
Living alone	29.3	29.0	30.6	0.82
Physical activity [†]	57.9	61.1	38.0	0.002
<i>Clinical conditions</i>				
Coronary heart disease	12.1	12.4	10.0	0.63
Cerebrovascular disease	4.7	4.5	6.0	0.63
Congestive heart failure	6.0	5.4	10.0	0.21
Peripheral artery disease	2.7	2.9	2.0	0.73
Hypertension	72.3	70.4	84.0	0.05
Lung disease	13.5	14.0	10.0	0.44
Osteoarthritis	19.5	18.2	28.0	0.10
Diabetes	29.9	28.3	40.0	0.10
Dementia	9.9	9.6	12.0	0.59
Parkinson's disease	1.6	1.9	-	0.32
Cancer	4.7	4.5	6.0	0.63
Depression	25.3	23.2	38.0	0.03
Vision impairment	23.6	22.6	30.0	0.25
Hearing impairment	22.8	22.9	22.0	0.88
Number of medications	3.3±2.2	3.2±2.2	3.9±2.2	0.03
<i>Biological markers</i>				
Total cholesterol (mg/dL)	196.6 ± 44.8	197.4 ± 44.2	191.8 ± 48.9	0.41
Albumin (g/dL)	4.2 ± 0.3	4.2 ± 0.3	4.2 ± 0.4	0.51

* Cognitive Performance Scale ranges from 0 (no cognitive impairment) to 6 (severe cognitive impairment)

[†] Percentage of participants reporting light intensity (aerobic) exercise performed for at least 2-4 hours per week during the last year

Table 2
Unadjusted and adjusted* means of physical function measures (dependent variable) according to history of falls.

	Unadjusted			Adjusted*		
	No fall event (n=314)	Fall event (n=50)	p	No fall event (n=314)	Fall event (n=50)	p
Physical performance measures						
4-m walking speed (m/s)	0.512 (0.017)	0.299 (0.042)	<0.001	0.498 (0.013)	0.378 (0.033)	0.001
Short Physical Performance Battery	6.987 (0.214)	4.333 (0.537)	<0.001	6.780 (0.154)	5.602 (0.396)	0.006
Muscle strength measure						
Hand Grip Strength (kg)	31.107 (0.843)	25.080 (2.093)	0.008	30.513 (0.667)	28.711 (1.688)	0.33
Functional status measures						
ADL scale score	1.296 (0.136)	2.440 (0.341)	0.002	1.398 (0.101)	1.885 (0.259)	0.08
IADL scale score	2.933 (0.146)	3.880 (0.365)	0.02	3.037 (0.102)	3.248 (0.261)	0.46

The Short Physical Performance Battery score (composed by usual gait speed, balance, and chair stand tests) ranges from 0 (worst performance) to 12 (best performance). ADL: Activities of Daily Living (range 0-7, a higher number indicates higher impairment). IADL: Instrumental Activities of Daily Living (range 0-7, a higher number indicates higher impairment)

* Adjusted for age, gender, physical activity, hypertension, osteoarthritis, diabetes, depression, number of medications