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ORIGINAL ARTICLE

Association between physical performance characteristics and independence in activities of daily living in middle-aged and elderly men

Marjolein EM den Ouden,[1] Marieke J Schuurmans,[2,3] Ilse EMA Arts[1,3] and Yvonne T van der Schouw[1]

[1]Julius Center for Health Sciences and Primary Care and [2]Department of Rehabilitation, Nursing Science and Sports, University Medical Center Utrecht, and [3]Faculty Chair Care for the Chronically Ill and Elderly, University of Applied Science Utrecht, Utrecht, the Netherlands

Aim: Functional status at one moment in time is a determinant of future functional status and survival. Physical deterioration tends to occur early in the disabling process; however, etiological questions remain. This study investigated the association between physical performance characteristics and functioning independently in middle-aged and elderly men.

Methods: A total of 400 independently-living men aged 40–80 years were included in this cross-sectional study. Preservation of function was measured using the Stanford Health Assessment Questionnaire. Physical characteristics were muscle strength and power by dynamometer, lung function, lower extremity function by physical performance score, and physical activity by Voorrips-questionnaire. Logistic regression analysis was used to estimate the association between potential determinants and the dichotomized Health Assessment Questionnaire score. The odds ratios (OR) were adjusted for age, body mass index, education, socioeconomic status, smoking, alcohol and number of chronic diseases.

Results: After adjustment for confounders, higher walking speed (OR = 2.96, 95% CI 1.31–6.72) and shorter time to carry out the chair stand test (OR = 0.84, 95% CI 0.76–0.94) were associated with a higher probability of being independent in activities of daily living (ADL). Borderline significant associations were found for higher lung function and higher leg strength with higher probability of being independent in ADL. No associations were found for grip strength, physical performance score, standing balance and physical activity.

Conclusion: Lower body function and lung function were associated with a higher probability of being independent in ADL. **Geriatr Gerontol Int 2012; ••: ••–••.**

Keywords: activities of daily living, aged, disability, independent living, physical function.

Introduction

The percentage of older persons (>65 years) in the general population is increasing. Aging in general is associated with a decline in exercise capacity, muscle strength and power, lung capacity, balance, and/or walking ability.[1] Ultimately these changes in the body can result in a decline of the ability to carry out activities of daily living (ADL). ADL decline can be a major reason for loss of independence in older persons.[2]

The functional status of a person is the level of functioning in ADL, work and leisure time. Functional status comprises different domains, namely: physical, social, emotional and cognitive function.[3] Functional status and disability are dynamic processes. In a cohort study of non-institutionalized persons aged 65 years and older, spontaneous recovery to no disability was found in 22.5% of the disabled participants.[4] Still, the functional status at one moment in time is a strong predictor of the survival and future functional status in older persons.[5]

Physical function is an important component of functional status. Physical disability is characterized by irreversible changes in the sensory-motor performance of a person.[3] Physical disability is present in 20–30% of independently-living older persons aged over 70 years.[6] Physical disability tends to occur early in the disabling process and is therefore suitable for interventions.[7]

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Correspondence: Ms Marjolein E.M. den Ouden MSc, Julius Center for Health Sciences and Primary Care, STR 6.131, University Medical Center Utrecht, PO Box 85500, 3508 GA Utrecht, the Netherlands. Email: m.e.m.denouden@umcutrecht.nl

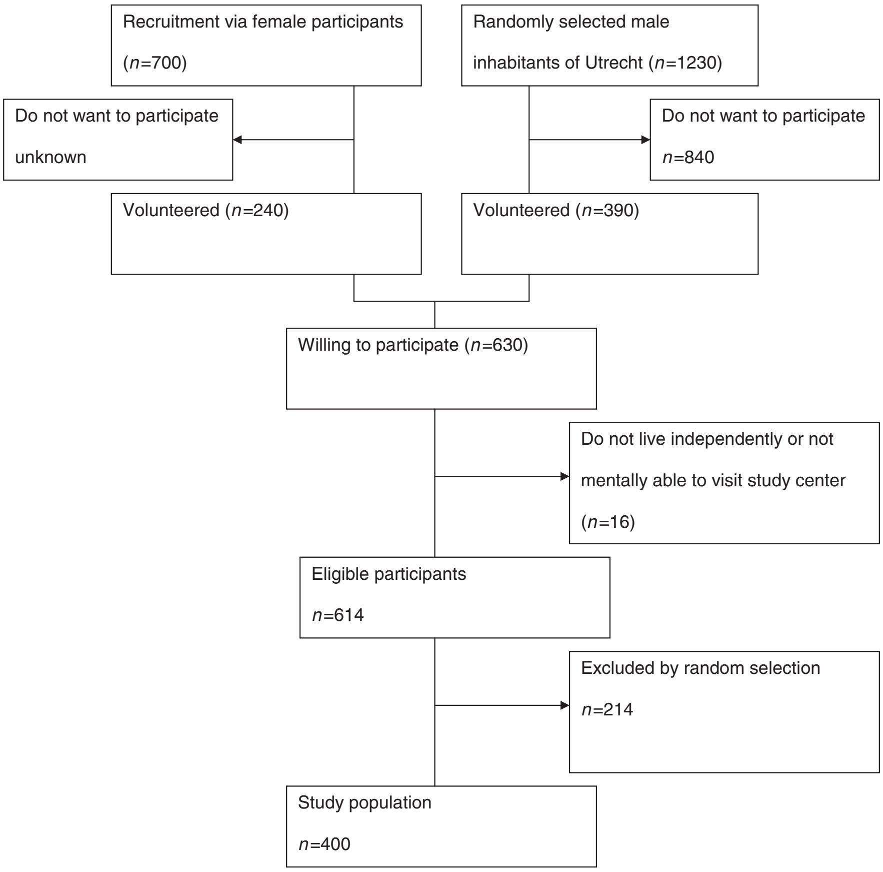

Figure 1 Flowchart of the inclusion of the participants of Hormonal Changes in the Aging Male and Epidemiologic Taskforce (HAMLET)

The aim of the present study was to investigate which physical characteristics (muscle capacity, lung function, lower extremity function and physical activity) are determinants of functioning independently in middle-aged and older persons. We hypothesized that higher scores on physical performance characteristics are associated with a higher probability of being independent in ADL.

Methods

Study design and population

In the present cross-sectional population-based study, we enrolled 400 independently-living men aged 40–80 years. Exclusion criteria were serious arthropathic deformation of the knee joint severely impairing mobility, serious illnesses interfering with the conduct of the study or interpretation of the results and current use of androgens or anti-androgens; for example, for treatment of hypogonademia or prostate cancer. Figure 1 shows the flowchart of the recruitment and inclusion of the participants; details on study design and recruitment have been published previously.[8] Briefly, the participants were recruited by means of asking female participants of other studies carried out by the department by letter whether they knew a possible interested male volunteer and sending invitation letters by post to a randomly selected male population aged 40–80 years from the municipal register of Utrecht. All participants gave written informed consent before enrolment in the study. The measurements were carried out in an outpatient clinic of the University Medical Center Utrecht. The study protocol was approved by the Institutional Review Board of the University Medical Center Utrecht. Data collection took place between March 2001 and April 2002.

Measurements

Participants visited the study center twice. During these visits, medical history was obtained and a physical examination was carried out. Height, weight and waist circumference were measured in a standing position with the participants wearing light indoor clothing without shoes. Participants were asked about current use of medications; these reports were checked by examining the labels of drugs brought to the clinic. Furthermore, information on age, education, smoking history and alcohol use was obtained. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared. Educational level was categorized as low, middle, high and university, and socioeconomic status was categorized into low, middle, high and scientific using the International Standard Classification of Occupations of Statistics Netherland. The self-reported smoking habits were classified as never, former or current smoking, and alcohol use was calculated in units/week. Comorbidity was categorized as no chronic diseases versus one or more chronic diseases based on medication use and self-reported physicians' diagnosis of cardiovascular disease, stroke, diabetes mellitus, chronic obstructive pulmonary disease and severe osteoarthritis.

Activities of daily living

The ability to carry out activities of daily life was measured using the Stanford Health Assessment Questionnaire (HAQ).[9] The HAQ consists of eight items; that is, activities, grip, reach, hygiene, walking, eating, arising and dressing/grooming. A total score of the previous items was calculated. The participants were categorized into either "fully independent" or "any grade of dependence". Fully independent was defined as a score of zero on the HAQ and any grade of dependence as a score of one or higher on the HAQ.

Physical characteristics

Lung function

Lung function was measured by peak expiratory flow rate (PEFR) using a PEFR-meter (asmaPLAN; Vitalograph, Buckingham, UK). Participants were instructed on how to use the PEFR-meter, and the trained clinician coached them to carry out three attempts and recorded the highest value.[10]

Muscle strength and power

Maximal muscle strength of the non-dominant hand and maximal isometric knee extension power were measured using an adjustable hand-held dynamometer (MicroFet dynamometer; Fabrication Enterprises, Elmsford, NY, USA).[11] The hand-held dynamometer has an excellent reliability and validity, with intraclass correlation = 0.98 and intraclass correlation = 0.99, respectively.[11] The average of three measurements was used for analysis. Maximal leg extensor strength was defined as the maximal strength for the right or the left leg, whichever was greater, in a position of 120 degrees of extension. For statistical analysis, the maximal strength was multiplied by the distance of the dynamometer to the knee joint (in m).

Lower extremity function

Functioning of lower extremities was assessed by measurements of standing balance, 8-ft walk and ability to rise from a chair.[12] The standing balance was assessed using three tests, namely side-by-side, semi tandem and full tandem position. The following classification was used: standing balance was scored 0 to 4, depending on the number of tests a person could complete. The time to complete the 8-ft walk and repeated chair stands were recorded.

Physical activity (by questionnaire)

As a measurement of what people actually do, the questionnaire on mobility in elderly developed and validated by Voorrips *et al.*[13] was used. It includes three types of physical activities during the preceding year; that is, household activities, sporting activities and other physically active leisure time activities. The total score of physical activity was used for the analysis.[13]

Statistical analyses

Baseline characteristics of the participants and determinants were reported as means with standard deviations for continuous variables, and numbers with percentages for categorical data.

Logistic regression analysis was used to estimate the association between potential determinants and being fully independent. The included determinants were lung function, hand grip strength, leg strength, standing balance, walking speed, score on the chair stand test and the total score on the Voorrips questionnaire. In the first model crude odds ratios (OR) and their 95% confidence interval (CI) were calculated; in the second model, we adjusted for age; and in the third model, we additionally adjusted for BMI, educational level, socioeconomic status, smoking, use of alcohol and the number of self-reported chronic diseases.

In secondary analyses, effect modification by age was studied by adding the interaction term between age and the determinant to a logistic regression model containing the two individual variables and confounders. When the interaction term was statistically significant, a stratified analysis was carried out according to two age categories (age group 40–59 years and age group 60–80 years). The statistical program SPSS (version 17.0; SPSS, Chicago, IL, USA) was used to analyze the data. Significance levels were set at $\alpha = 0.05$ for all tests.

Results

Table 1 shows the characteristics of the participants. Of 400 participants, 106 experienced any grade of dependence and 294 participants were fully independent, according to their HAQ-score. Dependence was most present on the subscales related to reach ($n = 65$), activities ($n = 47$) and arising ($n = 27$). Participants with

Table 1 Characteristics of the participants ($n = 400$)

	Any grade of dependence ($n = 106$) Mean ± SD	Fully independent ($n = 294$) Mean ± SD
Age (years)	66 ± 10	58 ± 11*
Height (cm)	176.2 ± 7.4	178.6 ± 7.1*
Weight (kg)	84.0 ± 13.2	82.9 ± 11.8
Body mass index (kg/m^2)	27.0 ± 3.5	26.0 ± 3.4*
Alcohol (units/week)	12 ± 13	13 ± 13
Smoking (pack years)	19.9 ± 21.3	15.6 ± 20.4*
No. chronic diseases, *n* (%)		
No chronic disease	60 (56.6)	146 (49.7)
One or more chronic disease	46 (43.4)	148 (50.3)
Education, *n* (%)		
Low	23 (21.7)	43 (14.6)
Middle	35 (33)	79 (26.9)
High	35 (33)	106 (36.1)
University	13 (12.3)	66 (22.4)
Socioeconomic status, *n* (%)		
Low	20 (18.0)	47 (16.0)*
Middle	40 (37.7)	73 (24.8)
High	37 (34.9)	132 (44.9)
Scientific	9 (8.5)	42 (14.3)
Lung function (m/s)	493.8 ± 122.2	564.6 ± 113.0*
Hand grip strength (N)	40.7 ± 9.2	44.3 ± 8.1*
Maximal isometric knee extension power (Nm)	365.8 ± 75.4	403.8 ± 78.6*
Lower extremity function (score)	8.2 ± 1.9	9.5 ± 1.9*
Standing balance (score)	4 ± 4	4 ± 3*
Walking speed (m/s)	1.9 ± 0.3	2.0 ± 0.4*
Chair stand test (s)	9.0 ± 2.64	8.2 ± 2.2*
Physical activity (score)	17.3 ± 7.7	18.4 ± 7.4
Household (score)	1.6 ± 0.5	1.7 ± 0.5
Sport (score)	1.7 ± 3.0	2.7 ± 3.7*
Leisure (score)	13.7 ± 7.6	13.9 ± 6.4

*$P < 0.05$.

any grade of dependence were significantly older (66 ± 10 years) compared with participants who were fully independent (58 ± 11 years). The groups also differed in BMI (27.0 ± 3.5 *vs* 26.0 ± 3.4 kg/m^2), smoking habits (19.9 ± 21.3 *vs* 15.6 ± 20.4 pack years) and socioeconomic status.

Table 2 shows the associations between physical characteristics and the ability to carry out ADL independently. In the fully adjusted model, higher walking speed (m/s) was associated with a higher probability of being independent in ADL (OR = 2.96, 95% CI 1.31–6.72). Table 2 also shows that more time (per second) to carry out the chair stand test was associated with a lower probability of being independent in ADL (OR = 0.84, 95% CI 0.76–0.94). A 50 L/min higher lung function and standard deviation higher leg strength tended to be associated with higher ability to carry out ADL independently (OR = 1.13, 95% CI 1.00–1.28, and OR = 1.30, 95% CI 0.97–1.75 for lung function and leg strength, respectively). No associations were found for hand grip strength and physical activity score with the ability to carry out ADL. Table 3 shows the association between standing balance and the ability to carry out ADL independently. The two highest quartiles of standing balance were associated with a higher probability of living independent compared with the lowest quartile (OR = 7.11, 95% CI 1.15–43.90 and OR = 6.16, 95% CI 1.08–35.12, respectively, *P* for trend $P = 0.09$). There was no effect modification by age for any of the determinants (*P*-values for interaction ranging from 0.20 to 0.62).

Discussion

In the present population-based cross-sectional study in middle-aged and elderly men, higher walking speed, less time to carry out the chair stand test, higher leg strength

Table 2 Odds ratio with 95% confidence interval for the association between physical performance characteristics and being fully independent in the ability to carry out activities of daily life

Determinants	Crude model		Age-adjusted model*		Fully adjusted model†	
	OR	95% CI for OR	OR	95% CI for OR	OR	95% CI for OR
Lung function (50 L/min)	1.31	1.18; 1.46	1.15	1.02; 1.29	1.13	1.00; 1.28
Hand grip strength (9 N)	1.55	1.22; 1.96	1.04	0.79; 1.38	1.06	0.79; 1.42
Leg strength (80 Nm)	1.61	1.27; 2.05	1.17	0.88; 1.55	1.30	0.97; 1.75
Walking speed (m/s)	2.91	1.36; 6.26	2.75	1.23; 6.16	2.96	1.31; 6.72
Chair stand test (s)	0.87	0.80; 0.96	0.93	0.90; 0.95	0.84	0.76; 0.94
Physical activity (score)	1.16	0.94; 1.42	1.15	0.92; 1.43	1.08	0.86; 1.35

*Adjusted for age. †Additionally adjusted body mass index, education, socioeconomic status, smoking, alcohol and number of chronic diseases.

Table 3 Odds ratios with 95% confidence interval for the association between standing balance (in quartiles) and being fully independent in the ability to carry out activities of daily life

Determinants	Crude model		Age-adjusted model*		Fully adjusted model†	
	OR	95% CI for OR	OR	95% CI for OR	OR	95% CI for OR
Standing balance						
Quartile 1	1.00		1.00		1.00	
Quartile 2	1.50	0.17; 13.23	3.18	0.33; 30.77	2.94	0.30; 28.87
Quartile 3	4.86	0.87; 27.39	6.63	1.07; 41.14	7.11	1.15; 43.90
Quartile 4	8.33	1.58; 43.83	6.09	1.06; 35.05	6.16	1.08; 35.12
P for linear trend	<0.001		0.09		0.09	

*Adjusted for age. †Additionally adjusted body mass index, education, socioeconomic status, smoking, alcohol and number of chronic diseases.

and higher lung function were associated with higher probability of being independent in ADL.

Lower extremity function was measured by standing balance, the 8-ft walk, the ability to rise from a chair and maximal leg extensor strength. The two highest quartiles of standing balance were associated with a higher probability of living independently (OR = 7.11, 95% CI 1.15–43.90, and OR = 6.16, 95% CI 1.08–35.12, respectively). These results were confirmed by other studies; in a longitudinal study with a follow-up period of 3 years, a relative risk (RR) was found of 0.81 (95% CI 0.66–0.89) for better balance and reduced risk for incident ADL disability.[14] In another 2-year follow-up study, a borderline significant association was found for the worst category of standing balance and higher probability of ADL disability (OR = 2.4, 95% CI 1.0–5.4).[15]

Our finding of an association between higher walking speed and higher probability to live independently is in line with the literature. In two longitudinal studies, higher walking speed was associated with reduced risk of ADL disability (RR = 0.65, 95% CI 0.52–0.82[14] and OR = 0.72, 95% CI 0.59–0.87,[16] respectively). One 6-year follow-up study showed that the two lowest categories of maximal walking speed were associated with higher risk of functional dependence at 6 years (hazard ratio [HR] = 5.15, 95% CI 2.71–9.77 and HR = 2.52, 95% CI 1.29–4.90, respectively).[17] In addition, higher walking speed was associated with later onset of functional dependence and better survival.[17]

The present study showed that more time to carry out the chair stand test was also associated with a lower probability of living independently. This result was confirmed by two other longitudinal studies with a follow up of 3 years and 1 year (RR = 1.54, 95% CI 1.29–1.83,[14] and RR = 2.1, 95% CI 1.2–3.5).[18] We found a borderline significant association between leg strength and the probability of being independent in ADL. In a similar cross-sectional study in postmenopausal women, an association was found per Nm maximum leg extensor strength and a lower probability of an impaired ADL (OR = 0.97, 95% CI 0.96–0.98).[19] In another, large cross-sectional study (n = 1753), an increased peak knee extensor power (per standard deviation) was also associated with a lower probability of ADL disability (OR = 0.75, 95% CI 0.59–0.97).[16]

Strikingly, all measures associated with lower extremity function were associated with a higher probability to live independently. A plausible biological mechanism that might explain the relationship between loss of lower extremity function and living independently is the extensive loss of muscle mass and strength. The number of excitable motor units declines with age, resulting in a decrease in motor units of approximately 25% until 80 years-of-age.[20] However, a loss of 50% has also been reported in persons older than 60 years-of-age.[20] A reduced number of motor units affect the ability to produce power in the muscles.[20] In combination with a sedentary lifestyle, inadequate nutrition and disease in the later years of life, this will result in reduced lower extremity function.[20] In addition, thigh and leg muscles will show atrophy over time.[20] These changes in the muscles can result in a muscle strength that might fall below the threshold to carry out ADL.[20] In contrast to the muscles of the lower body, the muscles of the upper body do not show this extent of atrophy.[20]

The present study identified lung function as a determinant of living independently. Few studies examined the association between lung function and being independent in ADL. A small prospective study ($n = 95$) showed that lung function was not associated with stability in ADL functioning over 2 and 4 years.[21] Lung function decreases with age, therefore a follow-up period of 4 years could be too small to notice changes in lung function.[21] Also, the small number of participants in that study ($n = 95$) would have reduced the power to pick up associations.[21] One large prospective study showed that lower peak expiratory flow was a predictor of disability during 8 years of follow up.[22] The mean age of participants in both studies was higher compared with the present study population (86.8 ± 2.3 years and 60 years and older, compared with 60.2 ± 11.3 years).[21,22]

The present study found no association between hand grip strength and living independently. Several studies[22–24] showed a beneficial effect of hand grip strength on ADL functioning. One study did not find this effect, but the association was borderline significant (OR = 0.84, 95% CI 0.69–1.02).[14] Again, all studies were longitudinal studies, with a follow-up time of 3 or 4 years.[14,22–24] These results might indicate that whereas grip strength at a particular moment is not a determinant of ADL independency, change in grip strength over several years might very well be. This was confirmed by previous studies, showing that isometric grip strength changes little until the sixth decade, but then decreases 1.0–1.5% per year from 50–70 years-of-age and 3% thereafter.[1,25] The (relatively young) age of the present study population could explain why we did not find an association between grip strength and the probability of living independently.

No association between physical activity and living independently was found in the present study. However, numerous studies showed that physical activity is important for maintaining functional ability at older ages, but also protects against the development of disability and the risk of future functional dependence.[2,26–29] The mean total score on the Voorrips of both groups is much higher compared with other studies that used the Voorrips Questionnaire, and very low scores of physical activity did not occur, showing that the present study population was relatively active.[13] In addition, in the present study, the difference in the physical activity of participants who lived independently was small compared with participants who had any grade of dependence.

A strength of the present study was the inclusion of a wide range of physical functioning measures. In most studies, a single aspect of physical functioning was included (e.g. muscle strength, physical activity or lung function). In addition, the age of the participants ranged from 40 to 80 years, which provided the opportunity to investigate the effect of physical characteristics on living independently in different age decades. This improves the external validity of the present study.

Fried *et al.* proposed a phenotype of frailty as the presence of three or more of the following criteria: unintentional weight loss, self-reported reduced energy level, reduced handgrip strength, slow walking speed and low level of physical activity.[6,30] The concepts of ADL disability and frailty are overlapping, but should be differentiated, as they confer specific care needs and the prognosis is different.[6] Nevertheless, future research could investigate whether interventions on ADL disability could also have beneficial effects on the frailty-status of a person.

A number of methodological characteristics of the present study are relevant for interpreting the data. Because of the cross-sectional design of the study, we have to be cautious with causal inference. Second, one of the inclusion criteria was that the men had to live independently. Therefore, the present study population was relatively healthy, and the differences in determinants between fully independent participants and participants experiencing any grade of dependence were small. Despite these small differences, we were able to show associations between physical characteristics and the probability of being independent in ADL. Finally, the present study was restricted to men, which precluded us from extrapolating the findings to women.

Future research should focus on the relationship of physical characteristics and living independently using a longitudinal design for better insight in the direction of associations. Also, intervention programs could be designed to investigate the effect of training lower extremity function and lung capacity on living independently. It seems that even at a younger age, lower extremity function is associated with living independently.

In conclusion, lower body function and lung function were associated with a higher probability of being independent in ADL.

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