Maturitas 69 (2011) 208–219

Contents lists available at ScienceDirect

Maturitas

journal homepage: www.elsevier.com/locate/maturitas

Review

Physical performance characteristics related to disability in older persons: A systematic review

Marjolein E.M. den Ouden[a,*], Marieke J. Schuurmans[b,c], Ilse E.M.A. Arts[a,b], Yvonne T. van der Schouw[a]

[a] *Julius Center for Health Sciences and Primary Care, UMC Utrecht, Utrecht, The Netherlands*
[b] *Faculty Chair Care for the Chronically Ill and Elderly, Hogeschool Utrecht, The Netherlands*
[c] *Department of Rehabilitation, Nursing Science and Sports, UMC Utrecht, Utrecht, The Netherlands*

A R T I C L E I N F O

Article history:
Received 21 January 2011
Received in revised form 18 April 2011
Accepted 19 April 2011

Keywords:
Physical performance characteristics
Functioning independently
Older people
Disability
Systematic review

A B S T R A C T

Background: Progressive disability develops with older age in association with underlying disease, comorbidity and frailty. Physical performance characteristics are important to improve the physical condition of older persons and therefore may be able to prevent or delay the onset of (progressive) disability. However lack of understanding of the physiology and etiology of functional decline leading to disability causes a problem in the development of effective preventive interventions. The aim of the present review is to determine which physical performance characteristics are determinants of disability in the older general population.
Methods: We searched systematically the electronic databases of PubMed (MEDLINE), CINAHL, Cochrane Library, Psychlit and Embase for cohort studies and randomized controlled trials assessing disability in the older general population. Outcomes of interest were handgrip strength, upper and lower extremity function, balance gait and physical activity. The searching strategy resulted in 22 studies included in the present systematic review.
Results: Although heterogeneity was present in the measurements of disability, consistent findings were shown for physical performance characteristics and disability. In general, a lower score of the physical performance characteristics was associated with a higher probability of (the development of) disability. The association for other aspects of gait (e.g. gait-step continuity, gait-step symmetry, path deviation and turning) and disability seems to be present, though the number of studies is limited.
Conclusion: In the present systematic review, associations were found for hand grip strength, upper and lower body strength, gait speed, physical activity and the probability of disability.

Contents

* Corresponding author at: Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, STR 6.131, PO Box 85500, 3508 GA Utrecht, The Netherlands. Tel.: +31 0 88 756 86 88; fax: +31 0 88 755 54 84.
E-mail address: M.E.M.denOuden@umcutrecht.nl (M.E.M. den Ouden).

0378-5122/$ – see front matter
doi:10.1016/j.maturitas.2011.04.008

1. Introduction

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 may result in a decline of ability to perform activities of daily living (ADL) or disability. Two types of disability are distinguished, namely progressive and catastrophic disability [2].

Progressive disability develops with older age in association with underlying disease, comorbidity and frailty [2,3]. Catastrophic disability is the result of an acute clinical event (e.g. hip fracture or stroke) [2,3]. The incidence rates of progressive and catastrophic disability are approximately the same (11.3 vs 12.1 per 1000 person-years), with no apparent differences between men and women [2]. However the rate of increase is higher for progressive disability compared to catastrophic disability [2].

Because people in general are getting older, it is important to try to prevent (progressive) disability. Physical performance characteristics are important to improve the physical condition of older persons and therefore may be able to prevent or delay the onset of (progressive) disability. In addition, physical measures are also important for the prevention of hip fractures and stroke, which are related to catastrophic disability [4,5].

Many studies have investigated the relation between physical measures (e.g. lower body strength, grip strength, balance and physical activity) and disability. However lack of understanding of the physiology and etiology of functional decline leading to disability causes a problem in the development of effective preventive interventions. The aim of the present review is to determine which physical performance characteristics are determinants of disability in the older general population.

2. Methods

2.1. Data sources

The electronic databases of PubMed (MEDLINE), CINAHL, Cochrane Library, Psychlit and Embase were systematically searched with the following search term: Outcome disability was defined as (“impaired”, or “decline”, or “declined” or “limitation” or “preservation”) AND (“physical functioning” or “disabilities” or “(instrumental) activities of daily living” or IADL or ADL or “physical performance”). The search was limited to the English and Dutch language and there was no restriction on year of publication. The references of the included articles were scanned to find other relevant studies. The last search was performed on March 7th, 2011. Both cohort studies and random controlled trial studies (RCT) were included. Cross-sectional studies were excluded for the present systematic review. Unpublished studies, abstracts, dissertations, theses and book chapters were also excluded.

2.2. Study selection

Fig. 1 shows the selection of the study selection process. First, all titles ($n = 4573$) were scanned independently by two researchers (M.E.M.O. and E.M.A.A.) based on the criteria “physical performance characteristics” (as determinants) and “functional status or disability” (as outcome). Articles were excluded if they did not reported data from an original study (e.g. reviews or meta analysis, unpublished studies, abstracts, dissertations, theses and book chapters) or included a study population focussing on older persons with a medical condition or no community based population. Second, the (remaining) abstracts ($n = 236$) were scanned independently by two investigators (M.E.M.O. and E.M.A.A.) based on the same criteria. Additionally, papers were excluded when they did not describe an etiologic relation between physical performance characteristics and functional status or disability. Third the selected full-text articles were read ($n = 45$) and the final selection was made. In this last step the reason for excluding articles were cross-sectional study design ($n = 8$), prediction study ($n = 6$), outcome ($n = 7$), study population ($n = 5$), determinant ($n = 3$). By scanning the references of the included studies, six additional studies were included. The searching strategy resulted in 22 studies included in the present systematic review.

2.3. Data extraction and methodological quality

The data extraction was performed independently by two investigators (M.E.M.O. and E.M.A.A.) and was based on the guidelines of the Cochrane Handbook 2009 (chapter 7) [6]. We assessed the methodological quality of the studies based on the guidelines of Cochrane Library [6]. The guidelines included description of the study population (e.g. sample size, age, percentage women and mortality), study design (e.g. length of follow-up or intervention and definition of functional outcome), collection of the data (e.g. description methods, percentage missing at follow-up, blinding, selection bias, randomization), attrition over time (e.g. drop out and missing data) and statistical analysis (e.g. sufficient analysis and correction for confounders). For each aspect one point was assigned to the study, by adding the points of the different aspects a total score was calculated. A higher score represents a higher methodological quality. The maximum score for cohort studies was 17 and the maximum score for RCT was 20.

3. Results

The characteristics of the 22 studies included in this review are shown in Table 1. Both longitudinal studies ($n = 18$) and randomized controlled trials ($n = 4$) were included. In the longitudinal studies the follow-up time ranged from 12 months to 28 years and during the follow-up period the participants were measured one to eight times. All RCTs had a follow-up period of one year and the participants were measured one to three times during this follow-up period.

The overall quality of the included studies was moderate to good. For cohort studies the methodological quality ranged from 10 to 16 points and for RCT from 11 to 18 points.

In the included studies functional status or disability was measured using different outcomes en methods. The outcomes of the studies were: (instrumental and basic) ADL ($n = 9$), (incident) disability ($n = 6$), functional limitations ($n = 3$), functional (in)dependence ($n = 2$), onset of mobility disability ($n = 1$) and functional status ($n = 1$). In all studies a questionnaire was used to assess functional status or disability. The most commonly used

Table 1
Characteristics of the included studies.

Authors	Study design	Participants			Outcome	Determinant(s)	Factors controlled for	Association measures	Methods score
		n	Age (years) ± sd	% women					
Avlund et al. [23]	Cohort	1396	80 vs 74–75	54	Onset of mobility disability	Physical activity	Not described	No vs strenuous PA[a] and onset of mobility disability men: OR = 2.9[1.2; 6.7]; women: OR = 4.2[2.0; 8.7] light vs strenuous PA men: OR = 1.6[0.7; 3.6]; women: OR = 1.6[0.8; 3.0]	16
Brach et al. [27]	Cohort	229	74.2 ± 4.3	100	ADL[b] and IADL[c]	Physical activity	Age, # chronic conditions, physical activity limited by health	Compared to less active women in 1995, the more active women in 1995 reported fewer difficulties with ADL, performed better on the physical performance test and walked faster	15
Bruce et al. [24]	Cohort	805	50–72	28	Disability	Physical activity	Age, gender, race/ethnicity, education years, smoking status, number of comorbid conditions and baseline HAQ-DI	After adjustment, the physically inactive participants had significantly more disability than the active participants regardless of weight ($p < 0.001$)	10
Chu et al. [20]	Cohort	414	73.1 ± 6.2	49.5	IADL and BADL[d]	Gait/balance disorder	Age, gender, living alone, educational level, usual level of exercise, smoking status, self-reported health status, number of doctor visits, income level and several potential comorbid conditions	Slow gait speed and IADL score RR = 2.85[1.37; 5.92]	12
Femia et al. [12]	Cohort	90	86.8 ± 2.3	74	ADL and IADL	Grip strength	All other variables (e.g. psychological (mastery, depression, subject's health) and other vitality determinants	Grip strength is not significant associated with ADL stability.	14

Foldvari et al. [14]	RCT[e]	80	74.8 ± 5.0	100	Functional status	VO_2 peak, max treadmill time, muscle strength, power and endurance, percent 1RM where peak power occurs.	Not done	Univariate relation between physical measures and the functional status score: PA ($r = -0.49$, $p < 0.001$), leg press power ($r = -0.47$, $p < 0.001$), leg press strength ($r = -0.43$, $p = 0.001$), VO_2 peak ($r = -0.40$, $p = 0.0003$), chest press power ($r = -0.35$, $p = 0.00270$, chest press strength ($r = -0.27$, $p = 0.0223$), upper back power ($r = -0.26$, $p = 0.02700$ and hip abductor power ($r = -0.18$, $p = 0.1353$)	11
Giampaoli et al. [8]	Cohort	140	71–91	0	Disability in ADL and IADL	Hand grip strength	Not described	Hand grip strength was associated with disability in persons ≥ 77 years (RR = 0.96, 95% CI [0.93; 0.99]) but not in persons ≤ 76 years (RR = 0.99, 95% CI [0.97; 1.01])	13
Gill et al. [21]	Cohort	1103	79.1 ± 5.0	74	Onset of functional dependence	Physical performance	Age, gender, number of chronic diseases	Categories (quarter) of physical performance and functional dependence worst: RR = 2.1[1.4; 3.0], Third: RR = 1.3[0.9; 1.9], Second: RR = 1.1[0.7; 1.6], Best: RR = 1.0	16
Gill et al. [17]	RCT	188	82.8 ± 5.0 (I) 83.5 ± 5.5 (C)	85 (I)[f] 74 (C)[g]	Disability	Intervention program	Recruitment strategy; level of physical frailty and disability on baseline	Overall, participants in the intervention group had less disability at 3, 7 and 12 months (*P*-values 0.48, 0.008 and 0.02 respectively)	18
Gill et al. [22]	RCT	188	82.8 ± 5.0 (I) 83.5 ± 5.5 (C)	85 (I) 74 (C)	Self-reported iADL	Intervention program	Not done	Intervention program on IADL disability Difference between intervention and control group at 7 and 12 months was 17.7% ($p = 0.036$) and 12.0% ($p = 0.143$), respectively	16

Table 1 (*Continued*)

Authors	Study design	Participants			Outcome	Determinant(s)	Factors controlled for	Association measures	Methods score
		n	Age (years) ± sd	% women					
Gill et al. [19]	Cohort	563	79.1 ± 4.7	74	ADL dependence	Transfer and balance, gait; chair stand, rapid gait, 360° turn, bending over, foot taps, hand signature	Age, gender, # medications, arthritis of the knee(s)	Qualitive performance tests and ADL dependence Stand from chair: RR = 2.5[1.4; 4.2], stand of toes: RR = 3.0[1.8; 5.0], stand on heels: RR = 2.7[1.7; 4.5], sit down to chair: RR = 1.8[1.1;3.0], stand with feet touching: RR = 1.3[0.8; 2.2], withstand sternal nudge: RR = 1.1[0.6; 1.8], balance on one leg: RR = 1.0[0.5; 2.0], tandem stand: RR = 1.2[0.6;2.4], step continuity: RR = 2.3[1.4;3.9], step symmetry: RR = 1.7[1.0;3.0], Turning: RR = 1.8[0.9; 3.6], path deviation: RR = 1.2[0.6; 2.4]	16
Guralnik et al. [18]	Cohort	1122	77.1	64.9	Disability in ADL	Summary performance score	Age, sex, # chronic conditions	Summary performance score and disability at four years of follow-up Score 4–6: RR = 4.2[2.3; 7.7], score 7–9: RR = 1.6[1.0; 2.6], score 10–12: *R* = 1.0	15
Hirvensalo et al. [7]	Cohort	720	71.8 ± 5.1 71.9 ± 5.4 73.6 ± 5.0 74.4 ± 5.5	68	Loss of independence	Physical activity	Sociodemographic factors, chronic conditions, smoking and earlier physical exercise	Mobility and physical activity related to loss of independence Mobile-active (reference) Mobile-sedentary men: OR = 0.91[0.22; 3.70], women: OR = 1.17[0.63; 2.22]; impaired-active men: OR = 1.14[0.26; 4.93], women: OR = 1.99[0.94; 4.22]; impaired-sedentary men: OR = 5.21[1.44;18.7], Women: OR = 2.92[1.52; 5.60]	15
Kuo et al. [15]	Cohort	1753	70.2 ± 7.5	46.2	(instrumental) ADL	Knee extensor power and usual gait speed	Age, sex, race, educational levels, BMI, cognitive performance, smoking status, alcohol intake, health perception, self-reported PA, walking device, pain, C-reactive protein, co-morbidities, usual gait speed/knee extensor power	Knee extensor power and ADL disability OR = 0.75[0.59; 0.97] Knee extensor power and IADL disability OR = 0.76[0.59; 0.98] Usual gait speed and ADL disability OR = 0.72[0.59; 0.87] Usual gait speed and IADL disability OR = 0.63[0.52; 0.77]	12

Landi et al. [25]	Cohort	2005	82.1 ± 7.0	78	Onset of disability	Physical activity	Age, gender, cognitive performance scale score, impaired vision, ischemic heart disease, congestive heart failure, stroke, peripheral vascular disease, COPD, osteoarthritis, depression, # medications and country	PA and risk of disability No PA: OR = 1.0 PA: OR = 0.67[0.53; 0.84] Age < 80 years, no PA: OR = 1.0, PA: OR = 0.62[0.41; 0.93] Age > 80 years, no PA: OR = 1.0, PA: OR = 0.70[0.52; 0.94]	16
Miller et al. [26]	Cohort	5151	78.2 ± 6.0	64	Functional limitations	Physical activity	Gender, age, follow-up year, atherosclerotic heart disease, hypertension, arthritis and diabetes	Physically active lifestyle in 1984 and functional limitations Severe vs moderate/none limitations: 1984–1986: OR = 0.45[0.35; 0.58], 1986–1988: OR = 0.47[0.36; 0.60, 1988–1990: OR = 0.74[0.59; 0.93] Severe or moderate vs none limitations: 1984–1986: OR = 0.68[0.58; 0.80], 1986–1988: OR = 0.57[0.47; 0.69, 1988–1990: OR = 0.84[0.65; 1.08]	14
Onder et al. [9]	Cohort	884	78.7 ± 8.0	100	Incident ADL disability	Balance, chair stand, walking speed lower extremity, putting-on blouse, purdue pegboard, grip strength and upper extremity	Age and race	Lower and upper extremity performance measures and incident ADL disability Balance: RR = 0.81[0.66; 0.89]; chair stands: RR = 1.54[1.29; 1.83]; walking speed: RR = 0.65[0.52;0.82] lower extremities summary performance score: *R* = 0.56[0.53; 0.83] purdue pegboard: RR = 1.21[1.02; 1.45]; grip strength: RR = 0.84[0.69; 1.02]; upper extremities summary performance score: RR = 0.75[0.61; 0.91]	11

Table 1 (*Continued*)

Authors	Study design	Participants			Outcome	Determinant(s)	Factors controlled for	Association measures	Methods score
		n	Age (years) ± sd	% women					
Ostir et al. [16]	Cohort	1365	73.3	53	ADL dependence	8-foot walk, chair stand, standing balance and summary performance score	Age, sex, # chronic diseases.	8-foot walk and ADL disability: Cat. 1: OR = 5.4[1.2;23.6]; cat. 2: OR = 4.3[1.0;19.0], cat. 3: OR = 3.6[0.8;15.7], cat. 4: OR = 1.0 Chair stands and ADL disability: Cat. 1: OR = 2.8[1.2; 6.4]; cat. 2: OR = 1.6[0.7; 3.9], cat. 3: OR = 1.0[0.4; 2.6], cat. 4: OR = 1.0 Standing balance and ADL disability: Cat. 1: OR = 2.4[1.0; 5.4]; cat. 2: OR = 2.5[1.2; 4.8], cat. 3: OR=1.0 Summary performance score and ADL disability: Score 1–4: OR = 6.2[2.4; 16]; Score 5–8: OR = 2.0[0.9; 4.2], Score 9–11: OR = 1.0	10
Phelan et al. [28]	RCT	201	77.1 ± 5.1 (I) 76.9 ± 5.2 (C)	64.9 48	ADL disability	Intervention program	Baseline differences in gender and ADL function	Incidence of disability in BADL (no ADL disability at baseline) Intervention: RR = 0.68 [0.27; 1.70], control: RR = 1.0 Incidence of improvement in ADL function (any ADL disability at baseline): Intervention: RR = 1.84 [1.05; 3.22], control: RR = 1.0 Incidence of worsening in ADL function (entire population) Intervention: RR = 0.71 [0.38; 1.30], control: RR = 1.0	18

Rantanen et al. [10]	Cohort	6089	54 ± 5.5	0	Functional limitations	Hand grip strength	Age, weight, height, education, occupation, smoking, PA and # chronic diseases	Lowest midlife grip strength and self-reported difficulty walking 0.8 km: OR = 1.25[0.93; 1.67], walking up 10 steps: OR = 1.28[0.93; 1.78], lifting 4.5 kg: OR = 1.94 [1.25;3.02], doing heavy household work: OR = 1.69 [1.69; 2.27], dressing: OR = 2.43[1.42; 4.15], bathing: OR = 2.06[1.18; 3.59], eating: OR = 2.33[0.99; 5.49], toileting: OR = 1.96[0.97; 3.95] Middle midlife grip strength and self-reported difficulty walking 0.8 km: OR = 1.07[0.83; 1.38], walking up 10 steps: OR = 1.12[0.85; 1.49], lifting 4.5 kg: OR = 1.57 [1.05; 2.34], doing heavy household work: OR = 1.31 [1.02; 1.70], dressing: OR = 1.65[1.01;2.71, bathing: OR = 1.76[1.07;2.92], eating: OR = 1.72[0.78; 3.80], toileting: OR = 1.84[0.98;3.46]	13
Sarkisian et al. [11]	Cohort	657	73.6 ± 5.2 72.1 ± 4.3	100	Functional difficulty	Grip strength	Age, education, # comorbidities, cognitive function, BMI, gait speed, grip strength, visual acuity, PA, social network score, Geriatric depression scale and enrollment site	Grip strength and new functional difficulty: OR = 0.92[0.84; 1.0]	13
Tinetti et al. [13]	Cohort	1471	79.4 ± 5.2 78.0 ± 5.1	71	IADL	Lower and upper extremity function	Gender, age, race, education, # chronic diseases, MMSE, living situation, proxy information	Project safety cohort Lower extremity and IADL: $\beta = -0.72$ ($p < 0.0001$) Upper extremity and IADL: $\beta = -0.19$ ($p = 0.06$) Precipitating events project Lower extremity and IADL: $\beta = -0.36$ ($p < 0.0001$) Upper extremity and IADL: $\beta = -0.34$ ($p = 0.0004$)	16

[a] PA: physical activity.
[b] ADL: activities of daily living.
[c] IADL: instrumental activities of daily living.
[d] BADL: basic activities of daily living.
[e] RCT: randomized controlled trial.
[f] I: Intervention group.
[g] C: Control group.

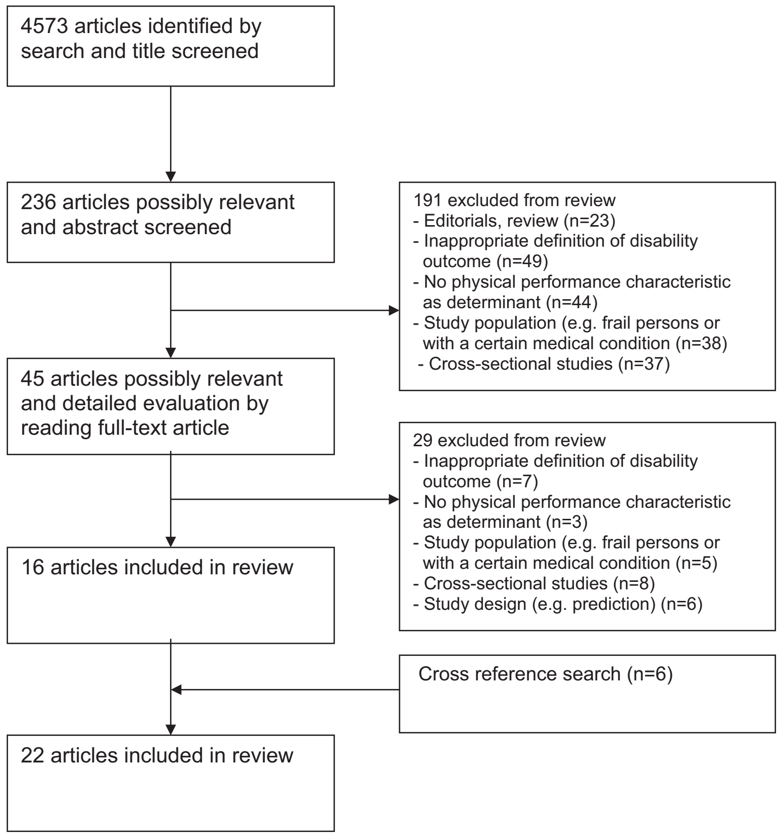

Fig. 1. Flow diagram of the study selection process.

measure was a selection of (i)ADL items ($n = 9$), followed by the Stanford Health Assessment Questionnaire ($n = 3$), Lawton's (I)ADL scale ($n = 3$), the Functional Status Questionnaire ($n = 2$), Modified Katz questionnaire ($n = 2$), Mobility-Help Scale ($n = 1$), Barthel Index ($n = 1$) and physical functioning questionnaire ($n = 1$). In the remaining study dependence was classified according to whether a person resided in nursing home, hospital or other assisted-living faculty or lived in the community but receiving publicly funded assistance [7]. In almost all studies (except two) the majority of the participants were female (range: 28–100%), in the remaining two studies only men were measured.

3.1. Physical performance characteristics

3.1.1. Hand grip strength

In total, four studies analyzed the impact of hand grip strength on (the development of) disability. In all studies hand grip strength was measured using a dynamometer. However the hand grip strength was calculated using different methods. The methods used were highest of two measures in the dominant hand [8], best of three attempts [9]; average of best results in 2 exams [10] and the average of both hands [11].

All studies showed a non-significant beneficial effect of hand grip strength on the development of disability. In a 4-year follow-up study higher hand grip strength was borderline significantly associated with reduced probability of new functional difficulty (odds ratio (OR) = 0.92, 95% CI [0.84; 1.00]) [11]. A 3-year longitudinal study found a borderline significant protective association for higher hand grip strength and incident ADL disability (relative risk = 0.84, 95% CI [0.69; 1.02] [9]. This was confirmed by another study, but only in participants over 77 years (relative risk (RR) = 0.96; 95% CI [0.93; 0.99] [8]. Also midlife grip strength is important for the ability to do heavy household work, dressing and bathing (OR range from 1.31 to 2.43) [10]. However the association was not present for eating and toileting [10]. Grip strength was not a significant predictor of ADL [12].

3.1.2. Lower and upper body strength

A total of eight studies focussed on lower and upper body strength. In the included studies, upper body strength was measured by the timed fingertaps and an upper extremity summary performance score (e.g. putting-on blouse, purdue pegboard and grip strength) [9,13]. Leg press power, summary performance score by Guralnik and the chair-stand test were used to assess lower body strength.

In the study of Onder and colleagues (2005) an upper extremity summary score was calculated. In this study a better score of upper extremity was associated with a lower probability of incident ADL disability (RR = 0.75, 95% CI [0.61; 0.91]) [9]. Another study also found a significant association between upper extremity strength (timed fingertaps) and IADL ($\beta = -0.34$, p-value <0.004) [13].

Leg press power and VO_2 peak were the only physiologic variables that contributed independently to FFS ($r = 0.57$, $p < 0.0001$) accounting for 32% of the variance in Functional Status Score (FSS) [14]. Higher knee extensor power was associated with a lower probability of ADL disability (OR = 0.75, 95% CI [0.59; 0.97]) [15]. More time to perform the chair stand test was associated with a higher probability of incident ADL disability and functional limitations (RR = 1.54, 95% CI [1.29; 1.83] [9]. In an other study only in the lowest quartile (≥16.5 s) more time to perform the chair stand test was associated with ADL disability (Q4 vs Q1: OR = 2.8, 95% CI [1.2; 6.4]) [16]. The inability to rise from a chair was associated with a higher probability of functional limitation. There was a significant association between worse lower extremity strength (by chair stands) and higher probability in IADL disability ($\beta = -0.36$, p-value < 0.001) [13].

There was only one RCT that focussed on improving lower body strength in an intervention program [17]. After a six month intervention, the intervention group had a non significant shorter time to perform the chair stand test compared to the control group ($p = 0.101$) [17]. However, the effect was present at the follow-up at 12 months ($p = 0.046$) [17].

3.1.3. Balance

In four studies balance was investigated in relation to living independently. Balance was measured by investigating maintaining of balance in different positions of the feet and withstand a sternal nudge [16–19].

A worse balance was associated with a higher probability of ADL dependence (Q3 vs Q1: OR = 2.4, 95% CI [1.0; 5.4]) [16]. In addition, a better balance was associated with a lower probability of incident ADL disability (RR = 0.81, 95% CI [0.66; 0.89]) [9]. In one study balance was not associated with ADL dependence [19].

After a six-month, home-based intervention participants in the intervention group had less IADL disability compared to participants in the control group at 7 months (difference: 17.7%, $p = 0.036$) [17]. However this effect was no longer present at 12 months (difference: 12.0%, $p = 0.143$) [17]. In a separate analysis of participants with severe frailty, the disability scores at 7 and 12 months were not significantly different between the intervention and control group [17].

3.1.4. Gait

In total five studies focussed on gait and aspects related to gait. In one study rapid gait speed was measured, all other studies reported usual gait speed. However the distance over which the gait speed was measured ranged from 2.4 m (8-foot) till 5 meter [9,15,16,19,20]. In two studies other aspects of gait were measured, namely gait-step continuity, gait-step symmetry, path deviation and turning [17,19].

In the two lowest quartiles, lower walking speed was associated with a higher probability of the onset of ADL disability (Q4 vs Q1: OR = 5.4, 95% CI [1.2; 23.6]) [16]. This result was confirmed in another study (OR = 2.85, 95% CI [1.37; 5.92]) [20]. Two studies found that higher walking speed was associated with a lower probability of incident ADL disability (OR = 0.65, 95% CI [0.52; 0.82] and OR = 0.72, 95% CI [0.59; 0.87]) [9,15].

Less step continuity was related with a higher probability of ADL dependence (RR = 2.3, 95% CI [1.4; 3.9] [19,21]. There was a borderline significant relation for less step symmetry and higher probability of ADL dependence (RR = 1.7, 95% CI [1.0; 3.0]) [19]. No relations were found for turning, path deviation and ADL dependence [19].

There was only one RCT that focussed on improving gait speed and gait related aspects in an intervention program. After a six months intervention, the intervention group had a significant higher timed rapid gait compared to the control group (difference: 17.7%, $p = 0.036$) [22]. However the effect was not present at the 12 month follow-up (difference: 12.0%, $p = 0.143$) [22]. The same effect was shown for other aspects of gait measured by the Performance Oriented Mobility Assessment (POMA) [22]. After a six months intervention, the intervention group had a significant higher POMA-score compared to the control group (difference: 12.2%, $p = 0.036$) [22]. Again the effect was no longer present at the 12 month follow-up (difference: 7.2%, $p = 0.183$) [22].

3.1.5. Summary performance score

Lower extremity function can also be assessed by a summary score of standing balance, walking speed and the ability to perform a sit to stand test. In three studies an additional summary performance score was calculated [16,18,19].

In a four-year follow-up study the Summary Performance Score (SPS) at baseline was associated with disability in ADL (SPS 10 to 12 vs SPS 4 to 6: RR = 4.2, 95% CI [2.3; 7.7]) [18]. This was confirmed by two other studies (OR = 6.2, 95% CI [2.4; 16] and RR = 2.1, 95% CI [1.4; 3.0]) [16,21]. These results showed that only the lowest category of the SPS was associated with a higher probability of ADL disability compared to the highest category of the SPS [16]. However the number of participants with a lower SPS score were small (11, 38 and 9 respectively) [16].

3.1.6. Physical activity

In total seven studies focussed on the relation between physical activity and disability. The correlation between Functional Status Score (FSS) and physical activity was −0.49 ($p < 0.001$) [14]. No physical activity compared to strenuous physical activity was associated with a higher probability of disability in men and women (men: OR = 2.0, 95% CI [1.2; 6.7], women: OR= 4.2, 95% CI [2.0; 8.7) [23]. However there was no association for light vs strenuous activity on the probability of disability in men and women (men: OR = 1.6, 95% CI [0.7; 3.6], women: OR = 1.6 95% CI[0.8; 3.0]) [23]. This was confirmed by two other studies, the association was present regardless of weight group (normal weight vs overweight) and age (<80 years and >80 years) [24,25]. In both men and women a sedentary lifestyle and impaired mobility were associated with a higher probability of disability (men: OR = 5.21, 95% CI [1.44; 18.7], women: OR = 2.92, 95% CI [1.52; 5.60]) [7]. Past physical activity level is important to delay the onset of disability, regardless of the severity of limitations [26]. Consistency in physical activity level is related to less ADL difficulty [27].

In a 1-year RCT leg press power and habitual physical activity level were the only two factors that contributed independently to the FFS ($r = 0.64$, $p < 0.001$) [28]. No effect of an exercise intervention program was shown among persons with no disability at baseline [28]. However the incidence of improvement in ADL function in persons with any ADL disability at baseline was higher in the intervention group compared to the control group (RR = 1.84, 95% CI [1.05; 3.22] [28].

3.2. Summary of findings

All studies showed a beneficial effect of higher hand grip strength on the development of disability. One study described that the association was only present in persons with a higher age, therefore this association seems to be modified by age. Both higher upper and lower body strength were associated with disability in all studies. An intervention program seems to work to delay or slow down the process into disability, but this is only based on a single study. In three out of four studies an association was found for better balance and disability. In a single RCT balance improved after the intervention, however the effect was not present at the 12 months follow-up. The association between higher gait speed and the development of disability was confirmed in all studies. The relation for other aspects of gait (e.g. gait-step continuity, gait-step symmetry, path deviation and turning) and disability seems to be present, though the number of studies is limited. Higher level of physical activity (regardless intensity) is associated with a lower probability of disability. An intervention program seems to work, but only in persons who experience any form of disability.

4. Discussion

In the present systematic review, we summarized the results of both cohort studies and randomized controlled trials on the relation between physical performance characteristics and disability.

In the literature is no consensus about the definition of the ability to live independently. Multiple synonyms are used, among others disability, ADL (in)dependence and functional status. It has been found that the prevalence of ADL disability is higher when disability is defined as "difficulty" compared to "dependence" [29]. In addition, the attribution or acceptance of disability by older persons themselves is important [30]. In the included studies of the present review eight questionnaires were used to describe the outcome related to living independently, which shows the diverse definition of the outcome.

All studies described an association between higher hand grip strength and the development of disability. Though, the associations between hand grip strength and disability were relatively small. A possible biological mechanism that can explain this is that isometric grip strength changes little until 60 years. From 50 to 70 years of age, grip strength decreases 1.0% to 1.5% per year and thereafter 3% per year [1,31]. However, one study showed that midlife hand grip strength is important in the development of future disability. Handgrip strength has often been used as an indicator of overall muscle strength. Overall general strengthening exercise can be used to improve hand grip strength and maybe in addition, delay or prevent the progression into disability.

Due to the limited number of studies investigating upper body strength, it is difficult to describe a conclusion. However both available studies showed that higher upper body strength was associated with a smaller probability of disability. Tinetti and colleagues (2005) used the finger tapping test as a measure of upper extremity measure [13]. In addition, the finger tapping test can also be used as a measure of motor function [32].

In the included studies different methods were used to assess lower body strength. Despite the different methods all studies found a significant relation with activities of daily living. The effect of an intervention program targeting lower body strength should be maintained over a longer period to demonstrate the effects.

In general worse balance was associated with a higher probability of disability. One study did not show this relation, despite a large study population ($n = 563$) [19]. A possible explanation is that the number of persons with an abnormal balance was small. One RCT showed that the effect was no longer present at 12 months after the intervention [17]. This suggests that (balance) training should be continued to improve balance in the long term.

The relation between gait speed and disability was confirmed in multiple studies. Intervention programs seem to work, but the program has to be continued over a longer period to have a long term effect on the delay of disability. In contrary, there is lacking evidence about the relation with the other aspect of gait, such as gait-step continuity, gait-step symmetry, path deviation and turning.

Higher physical activity is associated with a lower probability of disability. Also a beneficial effect was found of an intervention program. In addition the level of physical activity at a younger age is important to delay of prevent disability at older age. The effect of physical activity is comparable for men and women.

The overall quality of the included studies was moderate to good. However, not in all studies the data analysis was correctly performed regarding the research question. For example according to authors the study was a prediction study, but in the analysis the associations were adjusted for potential confounders. In addition, there might be a publication bias, due to the policy and statistical reasons of scientific journals to prefer studies with positive results. It therefore may result in an overestimation of the effect of the physical characteristics on the development of disability. However, studies were included in the present review that reported no association between physical performance characteristics and disability. The studies included used different definitions of disability and/or physical decline. As shown from previous studies the definitions, or description of the outcome, can give different results, therefore it is difficult to compare studies. Age is the most important determinant of disability, unfortunately not all studies adjusted for age. This can result in an overestimation of the effect.

We performed a systematic review on physical performance characteristics, to change or intervene in these physical characteristics. We included multiple physical performance characteristics which provides us an opportunity to intervene. The study population was not restricted to specific subgroups, such as persons with a certain disease, but rather the older general population.

More studies should be developed to confirm the results of the present systematic review. A small number of RCT were included in the review, therefore more focus on intervention programs to delay the onset of disability or prevent disability is important.

We recommend the inclusion of a younger population, to find out whether functional limitations at a younger age can already be recognized. In addition, preventive interventions could enable people, even in old age and with chronic conditions, to live independently. Preclinical disability is characterized by the development of early functional limitations or mild impairments long before it is clinically manifest [19]. Persons with preclinical disability do not have problems executing basic ADL but have an increased risk for developing disability or functional dependence [19]. Both Bruce and colleagues [24] and Rantanen and colleagues [10] performed studies which also include persons with a younger age (study population 50–72 and 45–68 years at baseline).

Physical performance measures are not only important in delaying the onset of disability, but also in predicting all cause mortality in the older general population [30]. The systematic review of Cooper and colleagues showed that lower grip strength (HR = 1.67, 95% CI [1.45; 1.93]), slower walking speed (HR = 2.87, 95% CI [2.22; 3.72]) and more time to perform a chair stand test (HR = 1.96, 95% CI [1.56; 2.45]) were associated with a higher risk of all cause mortality [30]. The present systematic review shows that even in an earlier stage physical performance characteristics have an association with disability or preservation of function. This may implicate that intervention in an earlier stage of the disability process is possible, to delay the onset or prevent disability. This should be further explored in future studies.

Progressive disability develops with older age in association with underlying disease, comorbidity and frailty [2,3]. In the present review we focussed on physical performance characteristics associated with progressive disability. In conclusion, despite a diverse definition of the ability to perform activities of daily living, associations were found for hand grip strength, upper and lower body strength, gait speed, physical activity and the probability to develop disability.

Contributors

M.E.M. den Ouden. I declare that I participated in study selection, data extraction, assessed the methodological quality, drafting the manuscript and that I have seen and approved the final version. I am supported by the Netherlands organization for health research and development (Grant: 60-61900-98-146).

M.J. Schuurmans. I declare that I participated in the critical revision of the manuscript and that I have seen and approved the final version.

E.M.A. Arts. I declare that I participated in the study selection, data extraction, critical revision of the manuscript and that I have seen and approved the final version. I am supported by the Netherlands organization for health research and development (Grant: 60-61900-98-146).

Y.T. van der Schouw. I declare that I participated in the critical revision of the manuscript and that I have seen and approved the final version.

Competing interest

M.E.M. den Ouden and E.M.A. Arts are supported by grant: 60-61900-98-146 from the Netherlands organization for health research and development. The funding organizations played no role in design and conduct of the study; collection, management, analysis, and interpretation of the data; or in the preparation, review, or approval of the manuscript.

Provenance and peer review

Not commissioned, externally peer reviewed. Peer review was directed independently of Yvonne van der Schouw (one of the authors and an Editor of Maturitas) by Prof Margaret Rees.

References

[1] Spirduso WW, Francis KL, MacRae PG. Physical dimensions of aging. Champaign, IL: Human Kinetics; 1995.
[2] Ferrucci L, Guralnik JM, Simonsick E, Salive ME, Corti C, Langlois J. Progressive versus catastrophic disability: a longitudinal view of the disablement process. J Gerontol A Biol Sci Med Sci 1996;51(3):M123–30. May.
[3] Arts IE, Schuurmans MJ, Grobbee DE, van der Schouw YT. Vascular status and physical functioning: the association between vascular status and physical functioning in middle-aged and elderly men: a cross-sectional study. Eur J Cardiovasc Prev Rehabil 2010;17(2):211–6. April.
[4] Jokinen H, Pulkkinen P, Korpelainen J, et al. Risk factors for cervical and trochanteric hip fractures in elderly women: a population-based 10-year follow-up study. Calcif Tissue Int 2010;87(1):44–51. July.
[5] Willey JZ, Moon YP, Paik MC, Boden-Albala B, Sacco RL, Elkind MS. Physical activity and risk of ischemic stroke in the Northern Manhattan Study. Neurology 2009;73(21):1774–9. Nov 24.
[6] Higgins JPT, Green S, The Cochrane Collaboration. Cochrane handbook for systematic reviews of interventions version 5.1.0 (updated March 2011); in press.
[7] Hirvensalo M, Rantanen T, Heikkinen E. Mobility difficulties and physical activity as predictors of mortality and loss of independence in the community-living older population. J Am Geriatr Soc 2000;48(5):493.
[8] Giampaoli S, Ferrucci L, Cecchi F, et al. Hand-grip strength predicts incident disability in non-disabled older men. Age Ageing 1999;28(3):283–8. May.
[9] Onder G, Penninx BW, Ferrucci L, Fried LP, Guralnik JM, Pahor M. Measures of physical performance and risk for progressive and catastrophic disability: results from the Women's Health and Aging Study. J Gerontol A Biol Sci Med Sci 2005;60(1):74–9. January.
[10] Rantanen T, Guralnik JM, Foley D, et al. Midlife hand grip strength as a predictor of old age disability. JAMA 1999;281(6):558–60. Feb 10.
[11] Sarkisian C, Liu H, Ensrud K, Stone K, Mangione C. Correlates of attributing new disability to old age. J Am Geriatr Soc 2001;49(2):134.
[12] Femia EE, Zarit SH, Johansson B. Predicting change in activities of daily living: a longitudinal study of the oldest old in Sweden. J Gerontol B Psychol Sci Soc Sci 1997;52(6):P294–302.
[13] Tinetti M, Allore H, Araujo K, Seeman T. Modifiable impairments predict progressive disability among older persons. J Aging Health 2005;17(2):239.
[14] Foldvari M, Clark M, Laviolette LC, et al. Association of muscle power with functional status in community-dwelling elderly women. J Gerontol A Biol Sci Med Sci 2000;55(4):M192–9. April.
[15] Kuo H, Leveille S, Yen C, et al. Exploring how peak leg power and usual gait speed are linked to late-life disability: data from the National Health and Nutrition Examination Survey (NHANES), 1999–2002. Am J Phys Med Rehabil 2006;85(8):650.
[16] Ostir GV, Markides KS, Black SA, Goodwin JS. Lower body functioning as a predictor of subsequent disability among older Mexican Americans. J Gerontol A Biol Sci Med Sci 1998;53(6):M491–5. November.
[17] Gill TM, Baker DI, Gottschalk M, Peduzzi PN, Allore H, Byers A. A program to prevent functional decline in physically frail, elderly persons who live at home. N Engl J Med 2002;347(14):1068–74. Oct 3.
[18] Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med 1995;332(9):556–61. Mar 2.
[19] Gill TM, Williams CS, Tinetti ME. Assessing risk for the onset of functional dependence among older adults: the role of physical performance. J Am Geriatr Soc 1995;43(6):603–9. June.
[20] Chu LW, Chiu AY, Chi I. Impact of falls on the balance, gait, and activities of daily living functioning in community-dwelling Chinese older adults. J Gerontol A Biol Sci Med Sci 2006;61(4):399–404. April.
[21] Gill TM, Williams CS, Richardson ED, Tinetti ME. Impairments in physical performance and cognitive status as predisposing factors for functional dependence among nondisabled older persons. J Gerontol A Biol Sci Med Sci 1996;51(6):M283–8. November.
[22] Gill TM, Baker DI, Gottschalk M, Peduzzi PN, Allore H, Van Ness PH. A prehabilitation program for the prevention of functional decline: effect on higher-level physical function. Arch Phys Med Rehabil 2004;85(7): 1043–9. July.
[23] Avlund K, Vass M, Hendriksen C. Onset of mobility disability among community-dwelling old men and women. The role of tiredness in daily activities. Age Ageing 2003;32(6):579.
[24] Bruce B, Fries J, Hubert H. Regular vigorous physical activity and disability development in healthy overweight and normal-weight seniors: a 13-year study. Am J Public Health 2008;98(7):1294.
[25] Landi F, Onder G, Carpenter I, Cesari M, Soldato M, Bernabei R. Physical activity prevented functional decline among frail community-living elderly subjects in an international observational study. J Clin Epidemiol 2007;60(5):518–24. May.
[26] Miller ME, Rejeski WJ, Reboussin BA, Ten Have TR, Ettinger WH. Physical activity, functional limitations, and disability in older adults. J Am Geriatr Soc 2000;48(10):1264–72. October.
[27] Brach JS, FitzGerald S, Newman AB, et al. Physical activity and functional status in community-dwelling older women: a 14-year prospective study 2003;163(21):2565–71.
[28] Phelan EA, Williams B, Penninx BW, LoGerfo JP, Leveille SG. Activities of daily living function and disability in older adults in a randomized trial of the health enhancement program. J Gerontol A Biol Sci Med Sci 2004;59(8):838–43. August.
[29] Wennie Huang WN, Perera S, VanSwearingen J, Studenski S. Performance measures predict onset of activity of daily living difficulty in community-dwelling older adults. J Am Geriatr Soc 2010;58(5):844–52. May.
[30] Cooper R, Kuh D, Hardy R. Mortality Review Group, FALCon and HALCyon Study Teams. Objectively measured physical capability levels and mortality: systematic review and meta-analysis. BMJ 2010;341:c4467. Sep 9.
[31] Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, et al. American College of Sports Medicine position stand, exercise and physical activity for older adults. Med Sci Sports Exerc 2009;41(7):1510–30.
[32] Jimenez-Jimenez FJ, Calleja M, Alonso-Navarro H, et al. Influence of age and gender in motor performance in healthy subjects. J Neurol Sci 2011;302(1–2):72–80. Mar 15.