Review

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

Marjolein E.M. den Ouden\textsuperscript{a,*}, Marieke J. Schuurmans\textsuperscript{b,c}, Ilse E.M.A. Arts\textsuperscript{a,b}, Yvonne T. van der Schouw\textsuperscript{a}

\textsuperscript{a} Julius Center for Health Sciences and Primary Care, UMC Utrecht, Utrecht, The Netherlands
\textsuperscript{b} Faculty Chair Care for the Chronically Ill and Elderly, Hogeschool Utrecht, The Netherlands
\textsuperscript{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.

© 2011 Elsevier Ireland Ltd. All rights reserved.
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, Psyclit 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 and 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.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study design</th>
<th>Participants</th>
<th>Outcome</th>
<th>Determinant(s)</th>
<th>Factors controlled for</th>
<th>Association measures</th>
<th>Methods score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avlund et al. [23]</td>
<td>Cohort</td>
<td>1396</td>
<td>Onset of mobility disability</td>
<td>Physical activity</td>
<td>Not described</td>
<td>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]</td>
<td>16</td>
</tr>
<tr>
<td>Brach et al. [27]</td>
<td>Cohort</td>
<td>229</td>
<td>ADL^b and IADL^c</td>
<td>Physical activity</td>
<td>Age, # chronic conditions, physical activity limited by health</td>
<td>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</td>
<td>15</td>
</tr>
<tr>
<td>Bruce et al. [24]</td>
<td>Cohort</td>
<td>805</td>
<td>Disability</td>
<td>Physical activity</td>
<td>Age, gender, race/ethnicity, education years, smoking status, number of comorbid conditions and baseline HAQ-DI</td>
<td>After adjustment, the physically inactive participants had significantly more disability than the active participants regardless of weight (p &lt; 0.001)</td>
<td>10</td>
</tr>
<tr>
<td>Chu et al. [20]</td>
<td>Cohort</td>
<td>414</td>
<td>IADL and BADL^d</td>
<td>Gait/balance disorder</td>
<td>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</td>
<td>Slow gait speed and IADL score RR = 2.85 [1.37; 5.92]</td>
<td>12</td>
</tr>
<tr>
<td>Femia et al. [12]</td>
<td>Cohort</td>
<td>90</td>
<td>ADL and IADL</td>
<td>Grip strength</td>
<td>All other variables (e.g. psychological (mastery, depression, subject’s health) and other vitality determinants</td>
<td>Grip strength is not significant associated with ADL stability.</td>
<td>14</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>N</td>
<td>Age (Mean ± SD)</td>
<td>Sex Ratio</td>
<td>Outcome Measures</td>
<td>Main Findings</td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>---------</td>
<td>-------</td>
<td>-----------------</td>
<td>-----------</td>
<td>------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Foldvari et al. [14]</td>
<td>RCT</td>
<td>80</td>
<td>74.8 ± 5.0</td>
<td>100</td>
<td>Functional status</td>
<td>Univariate relation between physical measures and the functional status score: PA (r = -0.49, p &lt; 0.001), leg press power (r = -0.47, p &lt; 0.001), leg press strength (r = -0.43, p = 0.001), VO2 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)</td>
<td></td>
</tr>
<tr>
<td>Giampaoli et al. [8]</td>
<td>Cohort</td>
<td>140</td>
<td>71-91</td>
<td>0</td>
<td>Disability in ADL and IADL</td>
<td>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])</td>
<td></td>
</tr>
<tr>
<td>Gill et al. [21]</td>
<td>Cohort</td>
<td>1103</td>
<td>79.1 ± 5.0</td>
<td>74</td>
<td>Onset of functional dependence</td>
<td>Categories (quarter) of physical performance and functional dependence worst: RR = 2.11 [1.4; 3.0], Third: RR = 1.30 [0.9; 1.9], Second: RR = 1.10 [0.7; 1.6], Best: RR = 1.0</td>
<td></td>
</tr>
<tr>
<td>Gill et al. [17]</td>
<td>RCT</td>
<td>188</td>
<td>82.8 ± 5.0 (I)</td>
<td>85 (I)</td>
<td>Disability</td>
<td>Intervention program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>83.5 ± 5.5 (C)</td>
<td>74 (C)</td>
<td></td>
<td>Recruitment strategy, level of physical frailty and disability on baseline</td>
<td></td>
</tr>
<tr>
<td>Gill et al. [22]</td>
<td>RCT</td>
<td>188</td>
<td>82.8 ± 5.0 (I)</td>
<td>85 (I)</td>
<td>Self-reported iADL</td>
<td>Intervention program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>83.5 ± 5.5 (C)</td>
<td>74 (C)</td>
<td></td>
<td>Not done</td>
<td></td>
</tr>
</tbody>
</table>
Table 1 (Continued)

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study design</th>
<th>Participants</th>
<th>Outcome</th>
<th>Determinant(s)</th>
<th>Factors controlled for</th>
<th>Association measures</th>
<th>Methods score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gill et al. [19]</td>
<td>Cohort</td>
<td>563</td>
<td>ADL dependence</td>
<td>Transfer and balance, gait; chair stand, rapid gait, 360° turn, bending over, foot taps, hand signature</td>
<td>Age, gender, # medications, arthritis of the knee(s)</td>
<td>Qualitative performance tests and ADL dependence</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>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]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guralnik et al. [18]</td>
<td>Cohort</td>
<td>1122</td>
<td>Disability in ADL</td>
<td>Summary performance score</td>
<td>Age, sex, # chronic conditions</td>
<td>Summary performance score and disability at four years of follow-up</td>
<td>15</td>
</tr>
<tr>
<td>Hirvensalo et al. [7]</td>
<td>Cohort</td>
<td>720</td>
<td>Loss of independence</td>
<td>Physical activity</td>
<td>Sociodemographic factors, chronic conditions, smoking and earlier physical exercise</td>
<td>Mobility and physical activity related to loss of independence Mobile-active (reference) Mobile-sedentary men: OR = 0.9[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 = 5.2[1.44; 18.7], Women: OR = 2.92[1.52; 5.60]</td>
<td>15</td>
</tr>
<tr>
<td>Kuo et al. [15]</td>
<td>Cohort</td>
<td>1753</td>
<td>Knee extensor power and usual gait speed</td>
<td>ADL</td>
<td>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</td>
<td>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]</td>
<td>12</td>
</tr>
<tr>
<td>Study</td>
<td>Cohort</td>
<td>Year</td>
<td>Mean Age ± SD</td>
<td>N</td>
<td>Study Characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>--------</td>
<td>------</td>
<td>---------------</td>
<td>----</td>
<td>---------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landi et al. [25]</td>
<td>Cohort</td>
<td>2005</td>
<td>82.1 ± 7.0</td>
<td>78</td>
<td>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</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miller et al. [26]</td>
<td>Cohort</td>
<td>5151</td>
<td>78.2 ± 6.0</td>
<td>64</td>
<td>Functional limitations Physical activity Gender, age, follow-up year, atherosclerotic heart disease, hypertension, arthritis and diabetes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onder et al. [9]</td>
<td>Cohort</td>
<td>884</td>
<td>78.7 ± 8.0</td>
<td>100</td>
<td>Incident ADL disability Balance, chair stand, walking speed lower extremity, putting-on blouse, purdue pegboard, grip strength and upper extremity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Landi et al. [25]**
- Cohort: 2005
- Mean Age: 82.1 ± 7.0
- N: 78
- Onset of disability
- Risk factors: Age, gender, cognitive performance scale score, impaired vision, ischemic heart disease, congestive heart failure, stroke, peripheral vascular disease, COPD, osteoarthritis, depression, medications and country

**Miller et al. [26]**
- Cohort: 5151
- Mean Age: 78.2 ± 6.0
- N: 64
- Functional limitations
- Risk factors: Gender, age, follow-up year, atherosclerotic heart disease, hypertension, arthritis and diabetes

**Onder et al. [9]**
- Cohort: 884
- Mean Age: 78.7 ± 8.0
- N: 100
- Incident ADL disability
- Risk factors: Balance, chair stand, walking speed lower extremity, putting-on blouse, purdue pegboard, grip strength and upper extremity
Table 1 (Continued)

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study design</th>
<th>Participants</th>
<th>Outcome</th>
<th>Determinant(s)</th>
<th>Factors controlled for</th>
<th>Association measures</th>
<th>Methods score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ostrir et al. [16]</td>
<td>Cohort</td>
<td>1365</td>
<td>ADL dependence</td>
<td>8-foot walk, chair stand, standing balance and summary performance score</td>
<td>Age, sex, # chronic diseases.</td>
<td>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</td>
<td>10</td>
</tr>
<tr>
<td>Phelan et al. [28]</td>
<td>RCT</td>
<td>201</td>
<td>ADL disability</td>
<td>Intervention program</td>
<td>Baseline differences in gender and ADL function</td>
<td>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</td>
<td>18</td>
</tr>
</tbody>
</table>

*Note: OR = Odds Ratio*
<table>
<thead>
<tr>
<th>Study</th>
<th>Cohort</th>
<th>Age (Mean ± SD)</th>
<th>Gender</th>
<th>Functionality</th>
<th>Hand Grip Strength</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rantanen et al. [10]</td>
<td>6089</td>
<td>54 ± 5.5</td>
<td>0</td>
<td>Functional limitations</td>
<td>Hand grip strength</td>
<td>Age, weight, height, education, occupation, smoking, PA and # chronic diseases and self-reported difficulty</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>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]</td>
</tr>
<tr>
<td>Sarkissian et al. [11]</td>
<td>657</td>
<td>73.6 ± 5.2</td>
<td>100</td>
<td>Functional difficulty</td>
<td>Grip strength</td>
<td>Age, education, # comorbidities, cognitive function, BMI, gait speed, grip strength, visual acuity, PA, social network score, Geriatric depression scale and enrollment site</td>
</tr>
<tr>
<td></td>
<td></td>
<td>72.1 ± 4.3</td>
<td></td>
<td></td>
<td></td>
<td>Grip strength and new functional difficulty: OR = 0.92 [0.84; 1.0]</td>
</tr>
<tr>
<td>Tinetti et al. [13]</td>
<td>1471</td>
<td>79.4 ± 5.2</td>
<td>71</td>
<td>IADL</td>
<td>Lower and upper extremity function</td>
<td>Project safety cohort Lower extremity and IADL: ( \beta = -0.72 (p &lt; 0.0001) ) Upper extremity and IADL: ( \beta = -0.19 (p = 0.06) ) Precipitating events project Lower extremity and IADL: ( \beta = -0.36 (p &lt; 0.0001) ) Upper extremity and IADL: ( \beta = -0.34 (p = 0.0004) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>78.0 ± 5.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- PA: physical activity.
- ADL: activities of daily living.
- IADL: instrumental activities of daily living.
- BADL: basic activities of daily living.
- RCT: randomized controlled trial.
- I: Intervention group.
- C: Control group.
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 hospital or other assisted-living facility 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.

3.1.2. 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 fngertaps and an upper extremity summary performance score (e.g. putting-on blouse, purdue pegboard and grip strength)] [9,10]. 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 (OR = 0.75, 95% CI [0.61; 0.91]) [9]. Another study also found a significant association between upper extremity strength (timed fngertaps) and IADL (β = −0.34, p-value <0.004) [13].

Leg press power and VO2 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)\cite{13}.

There was only one RCT that focussed on improving lower body strength in an intervention program\cite{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 ($p=0.101$)\cite{17}. However, the effect was present at the follow-up at 12 months ($p=0.046$)\cite{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\cite{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])\cite{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])\cite{9}. In one study balance was not associated with ADL dependence\cite{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%, $p = 0.036$)\cite{17}. However this effect was no longer present at 12 months (difference: 12.0%, $p = 0.143$)\cite{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\cite{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\cite{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\cite{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])\cite{16}. This result was confirmed in another study (OR = 2.85, 95% CI [1.37; 5.92])\cite{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])\cite{9,15}.

Less step continuity was related with a higher probability of ADL dependence (RR = 2.3, 95% CI [1.4; 3.9])\cite{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])\cite{19}. No relations were found for turning, path deviation and ADL dependence\cite{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%, $p = 0.036$)\cite{22}. However the effect was not present at the 12 month follow-up (difference: 12.0%, $p = 0.143$)\cite{22}. The same effect was shown for other aspects of gait measured by the Performance Oriented Mobility Assessment (POMA)\cite{22}. After a six months intervention, the intervention group had a significant higher POMA-score compared to the control group (difference: 12.2%, $p = 0.036$)\cite{22}. Again the effect was no longer present at the 12 month follow-up (difference: 7.2%, $p = 0.183$)\cite{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\cite{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])\cite{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]\cite{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\cite{16}. However the number of participants with a lower SPS score were small (11, 38 and 9 respectively)\cite{16}.

3.1.6. Physical activity

In total seven studies focussed on the relationship between physical activity and disability. The correlation between Functional Status Score (FSS) and physical activity was –0.49 ($p<0.001$)\cite{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])\cite{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])\cite{23}.

This was confirmed by two other studies, the association was present regardless of weight group (normal weight vs overweight and age (<60 years and >80 years)\cite{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])\cite{7}. Past physical activity level is important to delay the onset of disability, regardless of the severity of limitations\cite{26}. Consistency in physical activity level is related to less ADL difficulty\cite{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 ($r = 0.64$, $p < 0.001$)\cite{28}. No effect of an exercise intervention program was shown among persons with no disability at baseline\cite{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])\cite{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 there 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