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# Decline of Functional Capacity in Healthy Aging Workers

Remko Soer, PhD, Sandra Brouwer, PhD, Jan H. Geertzen, MD, PhD, Cees P. van der Schans, PhD, Johan W. Groothoff, PhD, Michiel F. Reneman, PhD

**ABSTRACT.** Soer R, Brouwer S, Geertzen JH, van der Schans CP, Groothoff JW, Reneman MF. Decline of functional capacity in healthy aging workers. *Arch Phys Med Rehabil* 2012;93:2326-32.

**Objectives:** (1) To study the natural decline in functional capacity (FC) of healthy aging workers; (2) to compare FC to categories of workload; and (3) to study the differences in decline between men and women.

**Design:** Cross-sectional design.

**Setting:** A rehabilitation center at a university medical center.

**Participants:** Volunteer sample of healthy workers (N=701) between 20 and 60 years of age, working at least 20 hours per week in the year prior to the study. Subjects were recruited via local press and personal networks.

**Interventions:** FC was measured with a 14-item Functional Capacity Evaluation. Demographics and health status were measured with a general demographic questionnaire and the RAND-36 questionnaire.

**Main Outcome Measures:** Workload was expressed by the workload categories, as described by the Dictionary of Occupational Titles. Descriptive statistics were used to present FC of workers. Change in FC by age was tested with segmented regression analyses with a cutoff point at 45 years of age.

**Results:** Significant but small declines of FC under age 45 years were present in repetitive reaching, hand dexterity, and energetic capacity. Up to 45 years of age, hand and finger strength increased on average. Over 45 years of age, lifting, carrying, hand and finger strength, and coordinative tests declined more compared with the group aged less than 45 years. Work capacity of men and women working in sedentary and light work was sufficient in all age categories. There are no differences in decline between men and women.

**Conclusions:** FC of healthy workers declines with age. This study demonstrates substantial variation in the type of FC decline among healthy workers between 20 and 60 years of age. Material handling, hand and finger strength, and hand coordination appear to decline the most in workers over age 45 years. The objective of rehabilitation is to maximize an individual's FC, particularly with respect to environmental demand. Thus, return to work programs must appreciate both FC

and workplace demands in an effort to restore/enhance equilibrium between the 2.

**Key Words:** Aging; Occupational health; Rehabilitation; Work capacity evaluation.

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**D**ECLINE IN FUNCTIONAL capacity (FC) with an increase of age is a well-known and normal phenomenon.<sup>1</sup> In normal physiology, adults' FC peaks at the ages of 20 to 30 and declines from then on.<sup>2</sup> Compared with workload, physical capacity was found to be lower in aging subjects working in physically demanding jobs.<sup>3</sup> Because of degenerative changes such as vascular stiffness in the cardiovascular system, aerobic capacity is known to decline significantly.<sup>4</sup> Handgrip strength is lower at older ages than at younger ages.<sup>1,3</sup> Much less, however, is known about the rate of the age-related decline of FC in relation to the workload. Additionally, it is unknown how decline takes place in different subtypes of FC, such as functional strength, static work capacity, coordination, repetitive work, or endurance. Furthermore, it is unclear whether there are differences in decline between men and women, and how these differences may reflect differences between physical work ability, because men and women may be working in different categories of physical load. After exercise physiology, men may be subject to a greater decline because dynamic strength (type 1 fibers) is known to decline faster than static strength (type 2 fibers), because men have larger percentages of type 1 fibers than women.<sup>5</sup> How this physiologic phenomenon relates to work ability is unknown.

Age-related decline may be especially relevant with regard to sustainable work participation until retirement or to work-rehabilitation programs for patients with illnesses or disability. When the workload remains constant over time and FC declines with age, an imbalance between FC and workload may occur following the load and capacity model.<sup>6</sup> For aging patients with disability, rehabilitation may be different than for younger patients because return to work goals could be more focused on adaptations in reducing workload instead of regaining capacity. It is suggested that older workers are less productive because of decline of FC. This may be accompanied by an increased duration of absenteeism.<sup>7</sup> Together, aging may pose a financial burden on employers, insurance, and social security systems. Whenever a worker cannot meet his or her work demands because of a decrease in FC because of aging, adaptations may be considered to restore this balance. This may be done by decreasing the workload (eg, adaptations to work content, work duration, or workplace) or by increasing FC (eg, training program, healthy diet). With these interventions, governments and

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## List of Abbreviations

DOT	Dictionary of Occupational Titles
FC	functional capacity
FCE	Functional Capacity Evaluation
PARQ	Physical Activity Readiness Questionnaire

employers may support the health of employees by taking into account variations in FC of aging workers.

The Dictionary of Occupational Titles (DOT) categorizes over 14,000 professions into 5 categories of physical work demands (sedentary, light, medium, heavy, and very heavy).<sup>8</sup> The DOT categorization is based on physical work demands only. When a natural decline in FC occurs, it is assumed that older workers would be more challenged to meet physically high demanding work. This assumption, however, is currently not validated. Functional Capacity Evaluations (FCEs) are evaluations of capacity of activities that are used to make recommendations for participation in work while considering the person's body functions and structures, environmental factors, personal factors, and health status.<sup>9</sup> In a previous study,<sup>10</sup> normative values for FCE were constructed in a sample of healthy working subjects and were directly related to the workload categories as provided by the DOT. A decline of FC with increasing age was assumed, but it is unclear how exactly this decline appears. It is challenging to broadly determine sufficient FC for work because of substantial variation in workplace demand among jobs. The results of this study may be of importance to employers, employees, insurers, and policymakers to gain insight in the decline of different types of FC with respect to the workload. Employers may be able to make effective interceptions on FC or workload of aging employees at risk. Policymakers may gain insight in FC and decline of FC when aging continues. One of the potential outcomes may be that for some professions, the workload cannot be met by most aging workers. Adaptations in workload or early retirements because of physical heavy work may then be considered.

In many European countries, including the Netherlands, there is new legislation to raise the retirement age from 65 to 67 years and to increase work participation in the age group above 55 years by converting voluntary early retirement schemes into fully funded pre-pension schemes.<sup>11</sup> Success may be influenced when changes in FC are small enough that the worker's FC remains equal to or higher than his or her work demands. Thus, it is of great concern to have insight in the natural decline of FC of healthy workers, and to compare this to work demands. This study had 3 objectives: the first objective of this study was to study the relation between age and different subtypes of FC. The second objective was to compare the differences described in the first objective to categories of workload. The third objective was to analyze differences in relations between age and FC between men and women. To answer these objectives, 3 study questions were asked: (1) Does FC decline with increasing age and does the decline vary by subtypes of FC? (2) Is FC with increasing age sufficient to meet the workload? (3) Are there differences in decline of FC with increasing age between men and women?

## METHODS

### Procedures

This study was a cross-sectional study design. Subjects were recruited via local press and personal networks from 2006 to 2008 in the Netherlands. Study participants were healthy workers. Inclusion criteria included participants between 20 and 60 years of age, who were working in a wide range of occupations. In total, over 180 different occupations were performed with different DOT codes. Participants were included who: met the criteria of the Physical Activity Readiness Questionnaire (PARQ),<sup>12</sup> had blood pressure in rest below 159mmHg (systolic)/100mmHg (diastolic), worked at least 20 hours per week, and did not have a leave of absence from work because of musculoskeletal complaints, mental health disorders, or other health problems for more than 2 weeks (5%) during 1 year prior to the study. All workers filled in a set of questionnaires prior to performing a

14-item FCE. On completion of the FCE, subjects received their personal results, a coupon of €15, and travel expenses. All subjects signed informed consent. This study was approved by the Medical Ethical Committee of the University Medical Center Groningen, The Netherlands.

### Questionnaires

Prior to the FCE, subjects filled in a set of questionnaires including general demographics such as sex, age, weight, height, education level, and work status. Self-reported health was assessed by means of the RAND-36,<sup>13</sup> a generic health measuring scale covering 9 domains of functioning and well-being: vitality, mental health, social functioning, general health perception, pain, role limitations (emotional problem), role limitations (physical problem), physical functioning, and health change.<sup>13</sup> Scores can range from 0 to 100, with higher scores indicating better self-reported health status. The results of this questionnaire were used for generalization purposes. Risks for performing physical exercise were assessed by means of the PARQ.<sup>12</sup> The PARQ is a screening list consisting of 7 questions concerning risk factors for musculoskeletal and cardiovascular pathology (eg, Do you feel pain in your chest when you do physical activity?). Subjects identifying 1 or more positive answers were excluded from this study.

### Functional Capacity Evaluation

Subjects performed a 2-hour, 14-item FCE based on the WorkWell protocol.<sup>14</sup> After an introduction to general FCE procedures, subjects were verbally instructed on how to perform each individual test. Subjects were allowed to begin a test when heart rate was below 70% of the age-related estimated maximum heart rate ( $220 - \text{age}$ ). Subjects were individually evaluated by 1 of 15 physical therapy students who had completed a 2-day FCE-training by a licensed WorkWell trainer specifically for this purpose. Interrater reliability of the WorkWell FCE is sufficient.<sup>15</sup> Tests were terminated when 1 of the following situations (whichever came first) occurred: (1) cardiac endpoint, when heart rate was above 85% of age-related estimated maximum ( $220 - \text{age}$ ). Heart rate was measured with a heart rate monitor. (2) Biomechanical endpoint, when loss of solid standing basis during lifting tasks or loss of control of the load was observed.<sup>15</sup> Biomechanical endpoints were determined by the evaluators. (3) Subject endpoints, when subjects stopped the test. Subjects were allowed and instructed to stop at any point they wished. Procedures, objectives, and psychometric qualities of each test are presented in appendix 1.

### Analyses

To answer the first research question (Does FC decline with increasing age and does the decline vary by subtypes of FC?), normality of data distribution was tested using the Kolmogorov-Smirnov test and by visual inspection of the skewness, kurtosis, P-P, and Q-Q plots. Linearity of decline in FC with an increase of age was tested, and regression analyses were calculated with sex and workload as covariates. Decline in FC by age was tested with segmented regression analyses in which a cutoff point of age was chosen, which led to the highest explained variance. This technique enables testing the difference in slope between the part before the chosen cutoff point and the part after that cutoff point.

To answer the second research question (Is FC with increasing age sufficient to meet the workload?), the physical demands were classified according to the DOT criteria (table 1). The FC was compared with the minimal required workload as defined by the DOT,<sup>8</sup> and the percentage of workers meeting the workload per age category was calculated.

Table 1: Physical Demand Characteristics of Work

Physical Demand Level	Occasional* (0%–33% of a workday)	Frequent* (34%–66% of a workday)	Constant* (67%–100% of a workday)
DOT 1: sedentary	4.5	Negligible	Negligible
DOT 2: light	9.1	4.5 <sup>†</sup>	Negligible
DOT 3: medium	22.7	9.1	4.5
DOT 4: heavy/very heavy	45.4	22.7	9.1

NOTE. Values are in kilograms. An example of physical demands is a carpenter (DOT code 860.281-010) who is categorized in physical demand level of medium. In this category, it can be required that the worker lifts weights up to 22.7kg occasionally.

\*Amount of force exerted to lift, carry, push, pull, or otherwise move objects, including the human body.

<sup>†</sup>Amount of force exerted to lift, carry, push, pull, or otherwise move objects, including the human body and/or walk/stand/push/pull of arm/leg controls.

To answer the third research question (Are there differences in decline of FC with increasing age between men and women?), a sex × age interaction variable was entered into the regression analyses for the group over 45 years of age. In all analyses,  $P < .05$  was considered statistically significant.

## RESULTS

Included in this study were 701 subjects. Demographic data and descriptive statistics and subjects' FCE scores are presented in table 2. Subjects were working in 180 different professions, differing in physical load, as categorized by the DOT. Men scored statistically higher on the RAND-36 subscales vitality, mental health, and role limitations emotional,

which is according to normative values of the Dutch population.<sup>16</sup> Women scored higher on social functioning. Men scored higher on strength tests and aerobic capacity, while women scored higher on coordinative and repetitive tests.

### Research Question 1: Does FC Decline With an Increase of Age?

FC was found to decline nonlinearly with an increase of age. FC was found to be relatively constant until the age of 45. Over 45 years of age, FC appeared to decline. Therefore, the influence of age on FC was calculated with a segmented regression analysis with a cutoff point of 45 years. The 45 years cutoff point was chosen because for the most tests, this was the cutoff

Table 2: Characteristics of Participants, Their Work, FCE Scores, and RAND-36 Scores

Characteristics	Total Group	Men	Women
n	701	447	254
Mean age ± SD (y)	41.4 ± 10.3	41.6 ± 10.4	41.1 ± 10.2
Body height (cm)	177.5 (8.9)	181.6 (7.2)	170.1 (6.6)
Body weight (kg)	77.7 (14.1)	83.1 (13.0)	68.0 (10.1)
Hand dominance (left-handed/right-handed/ambidextrous) (number)	83/585/33	63/362/22	20/223/11
Hours per week working	36.0 (8.6)	39.1 (7.5)	30.1 (7.7)
Years at present work	10.9 (9.7)	12.0 (10.1)	9.1 (8.6)
RAND-36 (0–100)			
1. Vitality	66.8 (12.4)	67.8 (11.8)	65.1 (13.2)*
2. Mental health	71.5 (10.0)	72.2 (9.8)	70.2 (10.1)*
3. Social functioning	86.2 (15.0)	84.9 (15.0)	88.7 (14.9)*
4. General health perception	75.3 (15.3)	74.7 (15.0)	76.4 (16.0)
5. Pain	91.3 (11.6)	91.3 (11.7)	91.4 (11.4)
6. Role limitation (emotional)	93.7 (21.4)	95.5 (17.6)	90.4 (26.4)*
7. Role limitation (physical)	93.8 (18.1)	93.9 (17.5)	93.6 (19.3)
8. Physical functioning	95.6 (9.1)	95.4 (9.8)	95.9 (7.5)
9. Health change	53.4 (16.0)	53.7 (15.9)	53.0 (16.4)
Lifting low (kg)	40.2 (15.2)	48.0 (12.6)	26.7 (8.1)*
Lifting high (kg)	17.7 (16.5)	21.1 (5.3)	11.8 (3.4)*
Carrying (kg)	42.0 (13.9)	48.9 (11.5)	29.9 (8.3)*
Overhead work (s)	259 (119)	275 (125)	230 (102)*
Dynamic bend (s)	45.5 (6.2)	46.3 (6.4)	44.0 (5.5)*
Repetitive reaching (s)	74.5 (11.4)	76.7 (11.6)	70.5 (10.0)*
Handgrip strength (kg)	43.4 (12.3)	50.2 (9.6)	31.9 (6.3)*
Pinch grip strength (kg)	5.4 (1.7)	6.1 (1.6)	4.3 (1.2)*
Palmar strength (kg)	7.8 (2.0)	8.6 (1.8)	6.3 (1.5)*
Key pinch strength (kg)	9.1 (2.2)	10.2 (1.9)	7.3 (1.4)*
Purdue Pegboard Test (no. of pins)	16.1 (1.9)	15.5 (1.7)	17.0 (1.8)*
Complete Minnesota Dexterity Test (s)	181.7 (22.5)	185.0 (23.6)	175.9 (19.2)*
Energetic capacity (ml <sup>-1</sup> .min <sup>-1</sup> .kg <sup>-1</sup> )	34.0 (7.2)	36.0 (6.7)	30.4 (6.4)*
Forward bend (s)	371 (310)	350 (266)	407 (371)*

NOTE. Values are mean ± SD or as otherwise indicated.

\*Statistically different at  $P = .05$ .

Table 3: Segmented Regression Analyses of Age, Sex, and Workload on FC

Test	Constant	Sex	DOT 2	DOT 3	DOT 4	Age <45	Δage 45	R <sup>2</sup>
Lifting low								
β (SE)	27.4 (3.1)	21.0 (0.9)	0.5 (1.2)	0.4 (1.2)	5.3 (1.9)	0.0 (0.1)	-0.3 (0.2)	0.49
P	0.00	0.00	0.68	0.74	0.00	0.78	0.10	
Lifting high								
β (SE)	9.9 (1.3)	8.9 (0.4)	0.4 (0.5)	0.8 (0.5)	3.9 (0.8)	0.1 (0.0)	-0.2 (0.1)	0.52
P	0.00	0.00	0.50	0.12	0.00	0.07	0.00	
Carrying								
β (SE)	29.6 (2.9)	18.6 (0.8)	1.5 (1.1)	0.6 (1.1)	5.8 (1.8)	0.0 (0.1)	-0.4 (1.6)	0.48
P	0.00	0.00	0.21	0.61	0.00	0.56	0.02	
Overhead work								
β (SE)	267.0 (33.6)	44.1 (9.6)	-17.8 (13.3)	-8.0 (13.0)	-1.8 (20.9)	-0.8 (0.9)	-0.1 (1.8)	0.04
P	0.00	0.00	0.18	0.54	0.93	0.39	0.98	
Dynamic bend								
β (SE)	39.9 (1.7)	2.0 (0.5)	-0.4 (0.7)	2.1 (0.7)	-0.1 (1.1)	0.1 (0.1)	-0.0 (0.1)	0.09
P	0.00	0.00	0.55	0.00	0.91	0.11	0.86	
Repetitive reaching								
β (SE)	59.5 (3.0)	5.4 (0.9)	-0.2 (1.2)	4.2 (1.2)	2.2 (1.9)	0.2 (0.1)	0.0 (0.2)	0.16
P	0.00	0.00	0.87	0.00	0.25	0.01	0.82	
Handgrip strength								
β (SE)	26.2 (2.5)	17.9 (0.7)	0.2 (1.0)	-0.4 (0.9)	4.8 (1.5)	0.2 (0.07)	-0.5 (0.1)	0.54
P	0.00	0.00	0.81	0.71	0.00	0.01	0.00	
Pinch grip strength								
β (SE)	3.7 (4.2)	1.9 (0.1)	0.3 (0.2)	-0.3 (0.2)	0.4 (0.3)	0.0 (0.0)	-0.0 (0.0)	0.30
P	0.00	0.00	0.11	0.06	0.16	0.08	0.21	
Palmar strength								
β (SE)	5.5 (0.5)	2.4 (0.1)	0.1 (0.2)	-0.6 (0.2)	0.1 (0.3)	0.03 (0.0)	-0.1 (0.0)	0.35
P	0.00	0.00	0.58	0.00	0.78	0.02	0.08	
Key pinch strength								
β (SE)	6.5 (0.5)	2.8 (0.1)	0.1 (0.2)	-0.4 (0.2)	0.8 (0.3)	0.03 (0.0)	-0.0 (0.0)	0.41
P	0.00	0.00	0.61	0.03	0.01	0.03	0.34	
Purdue Pegboard Test								
β (SE)	18.7 (0.5)	-1.3 (0.1)	-0.2 (0.2)	-0.7 (0.2)	-0.8 (0.3)	0.03 (0.0)	-0.1 (0.3)	0.29
P	0.00	0.00	0.29	0.00	0.01	0.04	0.00	
CMDT								
β (SE)	152.7 (5.9)	7.0 (1.7)	4.3 (2.4)	10.3 (2.3)	10.9 (3.7)	0.3 (0.2)	1.1 (0.3)	0.20
P	0.00	0.00	0.07	0.00	0.00	0.04	0.00	
Energetic capacity								
β (SE)	36.1 (1.9)	5.9 (0.5)	0.4 (0.7)	-1.3 (0.7)	0.2 (1.1)	-0.1 (0.1)	-0.1 (0.1)	0.21
P	0.00	0.00	0.55	0.08	0.88	0.02	0.57	
Forward bend								
β (SE)	624 (88.7)	-61.9 (25.2)	-72.5 (35.2)	-55.4 (34.5)	32.4 (54.9)	-4.7 (2.3)	6.0 (4.9)	0.03
P	0.00	0.01	0.04	0.11	0.56	0.05	0.21	

NOTE: Sex: female=0, male =1.

Abbreviations: CMDT, Complete Minnesota Dexterity Test; Δage 45, difference in slope of subjects over 45 years compared with subjects under 45 years of age; DOT 2, workload according to Dictionary of Occupational titles category 2 compared with category 1; DOT 3, Dot 3 compared to DOT 1; DOT 4, DOT 4 compared to DOT 1.

point where the largest variance could be explained from the 2 lines (table 3). Significant differences in the slope after 45 years of age (expressed by the Δage 45 column in table 3) in FC were observed in the following tests: lifting high ( $P<.01$ ), carrying ( $P=.02$ ), hand grip strength ( $P<.01$ ), Purdue Pegboard Test ( $P<.01$ ), and the Complete Minnesota Dexterity Test ( $P<.01$ ) after correction for sex and workload (see table 3).

### Research Question 2: Is Possible Decline of FC With an Increase of Age Sufficient to Meet the Workload?

The percentage of subjects whose lifting capacity relative to workload is insufficient is presented in table 4. Workload was defined as the required amount of lifting according to data of the U.S. Department of Labor.<sup>8</sup> The FC in all age groups is sufficient to meet the work demands of DOT 1 (sedentary

work) and 2 (light work). For professions such as nursing, carpentry, or car mechanics, where occasional lifting, pulling, and pushing up to 22.7kg is required (DOT 3), the capacity of men is in general sufficient for persons up to 60 years of age (3% of men >50y of age demonstrated insufficient capacity for lifting). For women, 20% to 35% were deemed with insufficient capacity to meet the work demands. This was independent of the age of the subject. For men working in physical heavy work (DOT 4; eg, bricklayer construction), 11% to 46% of subjects' lifting capacity was lower than the required workload.

### Research Question 3: Are There Differences in Decline of FC With an Increase of Age Between Men and Women?

There appeared no significant differences in decline between men and women.

Table 4: Percentage of Workers Whose Lifting Capacity Is Lower Than Required for Work Demands According to the DOT<sup>a</sup>

Age group	DOT 1 Male/Female		DOT 2 Male/Female		DOT 3 Male/Female		DOT 4 Male/Female	
	%	n	%	n	%	n	%	n
20–29	0/0	6/8	0/0	11/19	0/23	49/23	11/NA	9/0
30–39	0/0	10/15	0/0	20/16	0/20	66/26	46/NA	14/0
40–49	0/0	24/19	0/0	43/38	0/35	59/27	29/NA	14/0
50–59	0/0	16/22	0/0	59/22	3/22	36/16	30/NA	10/0

Abbreviation: NA, not available.

## DISCUSSION

The main results of this study confirm that material handling, hand strength, and coordination tests are nonlinearly related with age in healthy workers. Overall, capacity of coordinative tests and strength tests decline faster in subjects of 45 years of age and older compared with younger than 45 years of age. Static tests do not decline with higher age and energetic capacity appears to decline already before 45 years of age. Together, all these physical factors are responsible for a decreased capacity for work after 45 years of age; however, in most cases, FC of aging workers was sufficient to meet their work demands. This research has provided information about the decline of different work-related activities over age 45, which can be regarded as a prerequisite for work. For material handling tests, the results indicate that the work capacity of workers in DOT 4 can become a threat to overcome the workload, because these tests were directly related to work demands of the DOT. For the other tests, it is unknown how these capacity tests relate exactly to workload and therefore to work ability. It is postulated that this decrease in capacity is responsible for experienced difficulties of older workers to meet their workload, because they may experience lower reserves to fulfill their work demands.

Previous studies have found relationships between aging and hand and finger strength. A study by Mathiowetz et al<sup>17</sup> found considerably higher hand capacity results for U.S. adults from 20 to 45 years compared with our study, but hand capacity for subjects older than 45 years appear to be similar to results of our study. This difference led to a different age effect in the Mathiowetz<sup>17</sup> study compared with the current study. The cutoff point at 45 is in accordance with literature, in which previously, 45 years of age was found to be a cutoff point between chronological and functional age, meaning that decrease in functioning appears after 45 years of age.<sup>18</sup> For finger strength (pinch, palmar, and key pinch strength), results were similar to the Mathiowetz study,<sup>17</sup> and average scores remained relatively stable until 59 years. Isoinertial muscle strength of the back, neck, and shoulder muscles was previously found to decline for an average of 23% from 19 to 59 years in a study by Hamberg-van Reenen et al.<sup>1</sup> In this study, nonlinear decline in muscle strength was also found. For forward bending and overhead work, however, the results are capricious with large variation. It appears, therefore, that a decline in isoinertial muscle strength as found in Hamberg-van Reenen,<sup>1</sup> is only partly responsible for a decline in static holding time. This might be a logical finding at first sight; however, measuring at activity level permits more influences of psychosocial factors, such as motivation. Differences in outcome level (body functions level in contrast to activity level) may therefore lead to less comparable data. Other differences can be found between statistic analyses used in the current study versus the study by Hamberg-van Reenen.<sup>1</sup> For example, no covariates were included in their analyses.

The main additional value of the results of the present study is that tests were used that measure at activity level instead of measuring on body functions level as in other studies. Testing on activity level provides additional information about potential work participation. For this study, it can be concluded that aging does influence FC; only for a small percentage of workers does this decline mean that the workload cannot be met anymore. For physically demanding jobs (classified as DOT 4), a higher amount of workers appear to have difficulties in meeting their workload when aging continues, although no statistically significant differences could be observed. Table 4 represents the aging FC in relation to work demands. From this table, it can be concluded that for 70% of the mean FC of workers above 50 years of age, the FC is sufficient to work in heavy jobs. For women over 50 years of age, 22% of subjects' FC were deemed insufficient to meet demands of DOT 3. In general, the decline of material handling is of no relevance for work ability for persons working in DOT 1 to 3. Additionally, no changes were observed in decline between men and women. This finding was contrary to the hypothesis based on exercise physiology,<sup>5</sup> which stated that men and women would differ in decline in muscle strength.

## Study Limitations

The results of this research can be biased by the healthy workers effect, because this study used cross-sectional data only. Workers who are unable to meet their workload were unable to function well and were either not working or were working with substantial work absence (>5%) and were on that ground ineligible for participation in this study. Without this healthy worker effect, the effects observed in this study would be larger. Data from longitudinal studies would confirm such a hypothesis. On the other hand, the objectives of this study were to research the decline of healthy subjects who were still at work; therefore, the cross-sectional data in this research provides sufficient information to answer the research questions.

An important issue that should be addressed is the multifactor nature of aging and the observed relations between physical and cognitive functions. Decline also appears in cognitive and cortical functions. Studies on work ability remain complex, because differences between individuals are large in areas such as creativity, motivation, possibility of work adaptations, and laws. If the decline of capacity is considered in this context, individual workers and employers should be stimulated to tune and adapt the work environment to an optimum in order to sustain work ability. For policymakers, all different factors of decline should be weighed in order to make appropriate laws concerning the aging worker.

The cohort used in this study did not include workers over 60 years of age. This raises questions concerning work ability of workers beyond 60 among different DOT categories. Data of FC of healthy workers between 60 and 67 years of age are currently still unavailable; work ability in this group should be

tested, preferably in a longitudinal study design. Literature suggests that body functions do not decline linearly; therefore, the decline of capacity cannot be extended linearly to workers over 60 years of age.<sup>1</sup> With respect to this older group, data concerning FC is very valuable for governments, employers, employees, and insurers to gain insight in work capacity. In order to keep pensions affordable and guaranteed, the Dutch government made policies to increase the work participation of the aging Dutch work force. As a result, government and social partners (trade union movement and employers) debate to which extent these policies should be most effective. Suggested options are to increase retirement age from 65 to 67 years or to introduce flexible old age pension retirement ages in which workers who do 40 years of heavy work can retire.<sup>19</sup> What exactly is defined as heavy work, however, remains unclear. If it is unclear what happens to FC in relation to the demands of the job, then potentially hazardous situations may appear, most likely in physically demanding jobs. Another limitation of this study is the use of the DOT for the classification of workload. In many cases, the DOT is incapable of serving as an appropriate comparison method. For example, the execution of heavy work in DOT 4 is threatened by a decrease in material handling tasks, but material handling is not very relevant to other professions mostly stratified in other DOT categories. A decrease in hand dexterity may therefore influence the work ability of administrative assistants or other physically light professions.

For disabled aging workers, work rehabilitation should be regarded within the perspective of declining FC. Partly, FC may be increased, but a ceiling will be reached sooner because of natural aging. It is of importance for rehabilitation clinicians to realize that functional restoration programs should also include factors of reducing workload for older workers working in physically high demanding jobs to obtain healthy and sustained work participation.

## CONCLUSIONS

FC of healthy workers is declined in aging workers after 45 years of age. Overall, variety in decline of FC in healthy workers between 20 and 60 years of age is high. Lifting and carrying capacity, hand and finger strength and coordination appear to decline the most. Rehabilitation clinicians should take into account that natural decline in FC with an increase of age may be of importance for return to work programs.

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## APPENDIX 1. PROCEDURES, OBJECTIVES, AND PSYCHOMETRIC QUALITIES OF THE FCE

### Lifting Low

**Objective:** Capacity of lifting from table to floor. **Materials:** Plastic receptacle (40 × 30 × 26cm). A wall-mounted system with adjustable shelves and weights of 1.0, 2.0, and 4.0kg. **Procedure:** Five lifts from table at 74cm to floor and vice versa in standing position within 90 seconds. Four to 5 weight increments until maximum amount of kilograms was reached. **Test-retest reliability:** Intraclass correlation coefficient = .81 in low back pain patients.<sup>20</sup>

### Overhead Lifting

**Objective:** Capacity of overhead lifting task. **Materials:** Plastic receptacle (40 × 30 × 26cm). A wall-mounted system with adjustable shelves and weights of 1.0, 2.0, and 4.0kg. **Procedure:** Five lifts from table (74m) to crown height and

vice versa in standing position within 90 seconds. Four to 5 weight increments until maximum amount of kilograms was reached. **Test-retest reliability:** Intraclass correlation coefficient = .87 in low back pain patients.<sup>20</sup>

### Carrying

**Objective:** Capacity of 2-handed carrying. **Materials:** Plastic receptacle (40 × 30 × 26cm). A wall-mounted system with adjustable shelves and weights of 1.0, 2.0, and 4.0kg. **Procedure:** Twenty meters carrying at waist height with receptacle within 90 seconds. Four to 5 weight increments until maximum amount of kilograms was reached. **Test-retest reliability:** Intraclass correlation coefficient = .81 in low back pain patients.<sup>20</sup>

### Overhead Working

**Objective:** Capacity of postural tolerance of overhead working. **Materials:** Aluminum plate adjustable in height with 20 holes, bolts, and nuts and 2 cuff weights of 1.0kg each. **Procedure:** Standing with hands at crown height, manipulating nuts and bolts wearing cuff weights around the wrists. The time that position is held was measured (s). **Test-retest reliability:** Intraclass correlation coefficient = .90 in healthy subjects.<sup>21</sup>

### Forward Bending Standing

**Objective:** Measure postural tolerance of forward bending. **Materials:** A wall-mounted system with a shelf at 74-cm height, bolts, and nuts, and a weight (sandbag) of 5.0kg. **Procedure:** Standing with flexed trunk between 30° and 60°, manipulating nuts and bolts. Upper thoracic spine is loaded with a weighted bag of 5.0kg, placed between shoulder blades at approximately the third thoracic vertebrae. The time that position is held was measured (s). **Test-retest reliability without weight:** Intraclass correlation coefficient = .96 in low back pain patients.<sup>20</sup>

### Dynamic Bending

**Objective:** Capacity of repetitive bending and reaching. **Materials:** Twenty marbles and 2 bowls with a 14-cm diameter positioned at floor and crown height. **Procedure:** Standing with knees flexed between 0° and 30°, move marbles vertically from floor to crown height as fast as possible. Time needed to remove 20 marbles was scored (s). **Test-retest reliability:** Intraclass correlation coefficient = .72 in low back pain patients.<sup>20</sup>

### Repetitive Side Reaching

**Objective:** Capacity of fast repetitive side movements of the upper extremity. **Materials:** Thirty marbles and 2 bowls with a 14-cm diameter positioned at table height (74cm). **Procedure:** Sitting with bowls on wingspan distance, move marbles horizontally at table height from right to left with right arm as fast as possible and vice versa. Time needed to move 30 marbles was scored (s). Test was performed with right and left arm separately, both standing and sitting. Only right hand scores sitting are presented. **Test-retest reliability:** Intraclass correlation coefficient = .45 to .64 in low back pain patients.<sup>20</sup>

### Fingertip Dexterity

**Objective:** Capacity of fingertip dexterity. **Materials:** Purdue Pegboard (Model #32020).<sup>a</sup> **Procedure:** Sitting subject in front of the pegboard, placing pins with left and right hand as fast as possible in a 30-second trial. Average number of pins placed in 30 seconds over 3 trials in both hands was scored. Test was performed with right and left arm separately. Only

right hand scores are presented. **Test-retest reliability:** In 3 trials, the score is .91 in healthy subjects.<sup>21</sup>

### Hand and Forearm Dexterity

**Objective:** Gross movement coordination of fingers, hands, and arms. **Materials:** A Complete Minnesota Dexterity Test. **Procedure:** Sitting subject displacing 59 blocks in a predetermined way as fast as possible. Total displacing time needed to perform 4 trials with both hands was scored. **Reliability:** Four trial reliability in healthy subjects ranged from .77 to .98.<sup>22</sup>

### Handgrip Strength

**Objective:** Isometric grip strength. **Materials:** A hand dynamometer.<sup>b</sup> **Procedure:** In a seated position, the subjects held their shoulder adducted and neutrally rotated, elbow flexed at approximately 90°, and the forearm and wrist in neutral position. Grip strength of the right and left hand was measured in a 3-trial procedure. Only the second handgrip position will be reported. Average amount of kilogram force was scored. **Test-retest reliability:** Intraclass correlation coefficient >.93.<sup>23</sup>

### Finger Strength

**Objective:** Isometric tip, key, and palmar pinch strength. **Materials:** A pinch-grip dynamometer.<sup>b</sup> **Procedure:** In a seated position, the subjects held their shoulder adducted and neutrally rotated, elbow flexed at approximately 90°, the forearm and wrist in neutral position. For the tip pinch, subjects pinched for 3 seconds with the index finger above thumb. Facilitation of middle finger was not permitted. Palmar strength was measured with both index and middle finger on top and thumb below the dynamometer. Key strength was measured using pinch strength of thumb on top. Strength of right and left fingers was measured in a 3 trial procedure. Average kilogram was scored. **Test-retest reliability:** Intraclass correlation coefficient >.76 in healthy subjects.<sup>21</sup>

### Energetic Capacity

**Objective:** To predict the maximum oxygen consumption by submaximal Bruce treadmill test.<sup>24</sup> **Materials:** Treadmill with a slope capacity of 22% and a heart rate monitor. **Procedure:** The treadmill is set up with the stage 1 speed (2.7km/h) and grade of slope (10%), and the subject commences the tests. Every 3 minutes, slope and speed are adjusted following the Bruce protocol. Test is terminated when subject's 85% of age-related maximum is reached. Prediction of maximum oxygen consumption (VO<sub>2</sub>max) was done according to the following formula: VO<sub>2</sub>max = (16.62 + 2.74 [1.17 minutes of exercise] - 2.584 [weighting factor for sex] - .043 [years of age] - .0281 [kg body weight]), where the weighting factor for sex is 1 for men and 2 for women. **Test-retest reliability:** r=.99 in healthy subjects.<sup>24</sup>

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### Suppliers

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- b. Preston Corp, 65 Old US Highway 22, Clifton, NJ 08809.