

Musculoskeletal capacity and its changes among aging municipal employees in different work categories

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NYGÅRD C-H, LUOPAJÄRVI T, ILMARINEN J. Musculoskeletal capacity and its changes among aging municipal employees in different work categories. *Scand J Work Environ Health* 1991;17(suppl 1): 110-7. Aging effects on musculoskeletal capacity were studied among 83 subjects over a four-year period beginning at about 51 years of age, and the associations between work demands and musculoskeletal capacity were studied in a cross-sectional investigation comprising 137 subjects (mean age about 55 years). The follow-up study showed significant changes in musculoskeletal capacity, maximal isometric trunk strength having decreased 16-22 % and 9-10 % among the men and women, respectively, and maximal trunk muscular endurance and back mobility having increased 21 and 14 %, respectively, among the men. The cross-sectional study showed statistically significant differences in isometric hand-grip strength and leg mobility among the men and in isometric trunk flexion strength and trunk muscular endurance among the women in the three studied work groups. The investigation suggested that changes in musculoskeletal capacity can be marked after the age of 50 years and that physically heavy occupations do not maintain a sufficient level of capacity among elderly workers.

Key terms: aging, disability, gender, isometric muscular strength, job analysis, joint mobility, muscular endurance.

The functional capacity of humans declines with age (1). The decrease has been estimated to start at 25-30 years of age and decline on the average by 1 % per year (2). There is, however, much variation among individuals and functions. The greatest decline has been found for functions which demand complicated physical effort, such as anaerobic capacity (1).

The effect of aging on muscular strength has been studied widely during the last few decades (3-7). These studies indicate that muscular strength reaches its peak when a person is about 30 years old and thereafter declines with age. There is evidence that the decline is not linear, but rather accelerates at about the age of 50 years (6, 8). Most of the studies on the decline in strength in relation to age are based on cross-sectional comparisons, and they may therefore underestimate the effects of aging when compared with longitudinal studies (5). Although many different test batteries have been developed for evaluating physical capacity, there are few reports which deal with the musculoskeletal capacity of workers with different job demands. Physical capacity (including musculoskeletal capacity) has been found to be higher in subjects with a higher degree of vocational training (1, 9-11). Workers in mentally demanding jobs have also been found to be superior to those in physically demanding jobs in respect to different aspects of physical capacity [eg, grasping power, vertical and horizontal jumping (12), or muscular strength (1)]. Men who per-

ceived their jobs to be harder than an independent rating of the jobs had less perceived lifting capacity than the lower raters (13). In contrast, Clement (5) found no significant relationship between hand-grip strength and occupation among women, whereas men at the upper managerial and executive levels were stronger than the average population. Kamon & Goldfuss (14) could not find any significant differences in muscular strength among industrial workers involved in physically demanding materials handling.

The aims of the present study were to investigate the changes that occur in musculoskeletal capacity over a period of four years, including the changes in muscular strength, joint mobility, and musculoskeletal disability (follow-up study), and to study the differences in capacity in a cross-sectional sample of elderly men and women occupied in physical, mental, and mixed physical and mental jobs (cross-sectional study).

Subjects

The sample for the follow-up study comprised workers who participated in an investigation of musculoskeletal capacity in 1981 (15). The sample was representative of Finnish municipal occupations with physical, mental, and mixed physical and mental demands. From altogether 114 subjects, 19 persons refused or had other reasons not to participate in the follow-up measurements in 1985, and 12 persons were excluded because they had retired during the follow-up period. The follow-up sample therefore comprised 39 men and 44 women, all active occupationally at the time of the study. In addition to the aforementioned subjects, 54 new subjects with primarily either physi-

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cal or mental work demands were measured in 1985 so that there would be a larger amount of material on which to base the findings. These subjects were added to the follow-up sample because there were no statistically significant differences in the main capacity variables (table 1). The follow-up and the cross-sectional samples together (N=137) were analyzed cross-sectionally according to the content and demands of the jobs of the subjects.

Among both the men and the women in the follow-up sample some significant changes occurred in the

anthropometrics from 1981 to 1985 (table 2). The men's body mass index increased and their heights decreased during the follow-up period. The anthropometric changes of the men were about the same in all of the work groups. Body weight and body mass index had increased and body height had decreased among the women in the follow-up sample. In the cross-sectional study there were no statistically significant differences in the anthropometrics of the subjects between the three work groups, either among the men or the women (table 3).

Table 1. Maximal isometric right-hand grip, trunk flexion and extension strength, back mobility, and musculoskeletal disability in the follow-up and cross-sectional samples of the men and women.

Sample	Grip strength (kPa)			Trunk flexion strength (N · kg ⁻¹)			Trunk extension strength (N · kg ⁻¹)			Back mobility (mm)			Musculoskeletal disability index (arbitrary units)		
	Number of subjects	Mean	SD	Number of subjects	Mean	SD	Number of subjects	Mean	SD	Number of subjects	Mean	SD	Number of subjects	Mean	SD
<i>Men</i>															
Follow-up	39	90	21	36	6.9	1.3	35	7.5	2.2	39	59	8	39	7.0	3.4
Cross-sectional	24	100	19	23	6.8	1.1	23	8.4	1.5	24	60	13	25	6.1	2.2
<i>Women</i>															
Follow-up	44	80	19	44	5.0	1.3	44	5.5	1.6	44	54	11	44	6.7	3.0
Cross-sectional	24	80	17	24	4.1	1.3	18	4.5	1.6	23	57	12	23	5.8	2.5

Table 2. Age of the men and women after the follow-up and their body height, body weight, and body mass index before and the mean changes after the follow-up by work content group. (Mixed = mixed physical and mental)

Work content group	Age (years)		Height (cm)			Weight (kg)			Body mass index (kg · m ⁻²)		
			Before		Change	Before		Change	Before		Change
	Mean	SD	Mean	SD		Mean	SD		Mean	SD	
<i>Men</i>											
Physical (N = 17)	55.6	2.9	175.6	7.5	−0.8***	78.4	10.6	1.0	25.4	3.6	0.7*
Mixed (N = 12)	53.4	2.9	174.6	7.1	−0.4**	75.6	12.2	0.6	24.3	2.5	0.7**
Mental (N = 10)	55.8	2.8	176.0	5.0	−1.1***	81.3	8.3	−0.4	26.2	2.2	0.2
All (N = 39)	55.0	3.0	175.4	6.7	−0.7***	78.3	10.6	0.6	25.3	3.0	0.5***
<i>Women</i>											
Physical (N = 11)	56.3	2.9	159.0	7.8	−0.9**	63.2	8.7	1.2*	24.9	2.6	0.8**
Mixed (N = 9)	52.2	2.0	161.6	5.0	−0.4	66.4	6.1	1.2	25.3	1.8	0.7
Mental (N = 24)	55.4	4.0	160.5	5.1	−0.6***	67.6	10.9	1.3	26.3	4.3	0.7*
All (N = 44)	55.5	3.7	160.3	5.8	−0.6***	66.2	9.6	1.2**	25.7	3.5	0.7***

* P<0.05, ** P<0.01, *** P<0.001.

Table 3. Age, body height, body weight, and body mass index (BMI) of the men and women in the cross-sectional study by work content group.

Work content group	Number of subjects	Age (years)		Height (cm)		Weight (kg)		BMI (kg · m ⁻²)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Men</i>									
Physical	25	55.5	3.2	174.2	6.5	79.6	12.0	26.3	4.2
Mixed physical and mental	12	53.3	2.9	172.2	7.2	76.2	11.1	25.0	2.7
Mental	28	56.0	3.2	175.0	6.4	81.6	14.0	26.4	3.4
All	65	55.3	3.3	174.6	6.5	79.9	12.8	26.1	3.6
<i>Women</i>									
Physical	28	55.5	3.3	158.3	6.2	67.1	9.9	36.8	3.8
Mixed physical and mental	9	52.2	2.0	161.2	5.1	67.5	7.0	26.0	2.5
Mental	35	54.9	3.8	160.4	5.0	68.6	9.9	26.7	3.8
All	72	54.8	3.5	159.7	5.6	67.9	9.5	26.6	3.6

Methods

The contents and demands of the different occupations were analyzed by the AET (Arbeitswissenschaftliche Erhebungsverfahren zur Tätigkeitsanalyse) job analysis method (16). According to the job analysis, three dominating work content groups were formed (17). The groups were homogeneous according to the physical, mental, or mixed physical and mental demands of the work.

The maximal isometric muscular strength of the trunk flexors and extensors was measured with a calibrated dynamometer with the subjects in a standing position (18). A sit-up test (19) was done to measure the dynamic endurance strength of the trunk flexors. Maximal isometric hand-grip strength was measured for the right hand with a commercial, clinical device (Martin Vigorimeter, Germany).

The forward mobility of the lumbar back was assessed with the subjects in a standing position. The increase in the length of the subjects' spine between Th₁₂ and S₁ was measured when the back was bent forward with the knees kept straight (20). The side-ward bending of the back was measured with an inclinometer with the subjects in a standing position (20) (Myrin, Lic Rehab, Solna, Sweden). The tightness of the knee flexors was tested with a straight-leg raising test (21) and measured with an inclinometer (Myrin). The results of the sideward bending of the back and straight-leg raising tests are given only for the right side because there were no statistically significant differences between the two sides.

Musculoskeletal disability was assessed from the results of 11 different tests, from which an index was formed (table 4). The index included tests of muscu-

Table 4. Contents of the musculoskeletal disability index.

Item	Range of scores	Scale
Overweight (22)	0–3	1 = $\geq 27 \text{ kg} \cdot \text{m}^{-2}$ 2 = $\geq 30 \text{ kg} \cdot \text{m}^{-2}$ 3 = $\geq 32 \text{ kg} \cdot \text{m}^{-2}$
Back mobility (sideward and forward) (23)	0–3	1 = restricted to the right 1 = restricted to the left 1 = restricted forward
Sit-ups (19)	0, 2	2 = women, $< 5 \text{ times } 30 \cdot \text{s}^{-1}$ 2 = men, $< 8 \text{ times } 30 \cdot \text{s}^{-1}$
Back-ups (24)	0, 2	2 = $< 1 \text{ time}$
Arm mobility (20)	0–2	1 = restricted to the left 1 = restricted to the right
Hand grip strength (15)	0–2	1 = left hand, $< 50 \text{ kPa}$ 1 = right hand, $< 50 \text{ kPa}$
Straight-leg raising (21)	0–2	1 = restricted to the left $< 80^\circ$ 1 = restricted to the right $< 80^\circ$
Hip and sacroiliac joint mobility (21)	0–2	1 = pain and restricted mobility to the left 1 = pain and restricted mobility to the right
Walking	0, 4	4 = clearly difficult
Walking on toes	0, 1	1 = impossible
Squatting	0–3	3 = impossible
Maximal score	26	

Table 5. Maximal isometric right-hand grip and trunk flexion and extension strength of the men and women before and the mean changes after the follow-up by work content group.

Work content group	Grip strength (kPa)				Trunk flexion (N · kg ⁻¹)				Trunk extension (N · kg ⁻¹)			
	Number of subjects	Before follow-up		Change	Number of subjects	Before follow-up		Change	Number of subjects	Before follow-up		Change
		Mean	SD			Mean	SD			Mean	SD	
<i>Men</i>												
Physical	17	91	26	-12	15	8.6	2.1	-2.1***	14	8.9	2.2	-1.9***
Mixed physical and mental	12	97	19	+1	11	9.6	1.9	-2.5***	11	9.8	2.1	-2.0**
Mental	10	104	28	-6	10	9.0	1.9	-2.0**	10	8.9	2.2	-1.0
All	39	96	25	-7*	36	9.0	2.0	-2.2***	35	9.2	2.1	-1.7***
<i>Women</i>												
Physical	11	78	14	-5	11	5.7	2.0	-1.2*	11	6.2	2.3	-0.9
Mixed physical and mental	9	91	19	+2	9	6.3	1.3	-0.9**	9	6.5	1.5	-0.3
Mental	24	84	15	-8	24	5.7	1.8	-0.6	24	6.5	2.0	-1.1***
All	44	85	16	-5	44	5.8	1.7	-0.8**	44	6.4	2.0	-0.9***

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

lar strength, mobility of joints, and simple functional tasks (eg, squatting). A trained physiotherapist scored the degree of disability according to written instructions and limits. A normal function was scored zero, and disabilities were scored from 1 (mild disability) to 4 (severe disability). The index score ranged from 0 (very good) to 26 (very poor).

The differences in the means between the three work groups were statistically tested with a one-way analysis of variance. Paired comparisons were made for each individual taking part in both the base-line and the follow-up measurements, and the differences were tested with the paired Student's *t*-test. The differences were considered to be statistically significant when the probability values were less than 0.05.

Results

Four-year follow-up study

Muscular strength. The maximal isometric gripping strength of the right hand decreased 7 kPa among the men ($P < 0.05$) and 5 kPa among the women (table 5). There were no statistically significant changes among the work content groups. Only in the mixed work group was the hand grip slightly better after the follow-up, although the difference was not significant. The trunk flexion and extension strength had decreased during the follow-up period both among the men ($P < 0.001$) and the women ($P < 0.01$ – 0.001) (table 5). The trunk flexion strength had decreased significantly in all of the work groups except among the women in the mental work group. Trunk extension strength decreased significantly among the men in mental work ($P < 0.001$) and among the women in physical ($P < 0.001$) and mixed work ($P < 0.01$). The greatest changes were in trunk flexion strength among the men, for whom the trunk strength had decreased 24 % from the first measurements in 1981.

Trunk muscular endurance had increased significantly among the men ($P < 0.01$), especially among the men in physical and mental work ($P < 0.05$) (table 6), whereas there were no statistically significant changes among the women.

Mobility. The mobility of the lumbar back of the men had increased to some extent ($P < 0.05$), especially among the men in mixed work ($P < 0.01$) (table 7), whereas there were no statistically significant changes among the women.

Musculoskeletal disability. The musculoskeletal disability index remained unchanged during the follow-up period for both the men and the women (table 8). There were no significant changes for the work content groups either.

Table 6. Trunk muscle endurance (sit-ups in 30 s) of the men and women before and the mean change after the follow-up by work content group.

Work content group	Number of subjects	Sit-ups (times $\cdot 30 \text{ s}^{-1}$)		
		Before follow-up		Change
		Mean	SD	
<i>Men</i>				
Physical	13	6.6	1.9	+1.9*
Mixed physical and mental	8	8.3	2.2	+0.9
Mental	9	11.5	4.6	+2.7*
All	30	8.4	4.9	+1.8**
<i>Women</i>				
Physical	11	4.4	4.7	-0.4
Mixed physical and mental	9	1.3	7.7	+0.6
Mental	22	6.0	4.4	+0.2
All	42	5.9	3.9	+0.1

* $P < 0.05$, ** $P < 0.01$.

Table 7. Mobility of the lumbar back of the men and women between discs Th₁₂ and S₁, before and the mean change after the follow-up by work content group.

Work content group	Number of subjects	Mobility (mm)		
		Before follow-up		Change
		Mean	SD	
<i>Men</i>				
Physical	17	56	10	+ 2
Mixed physical and mental	12	50	15	+ 10**
Mental	10	58	10	+ 1
All	39	55	12	+ 4*
<i>Women</i>				
Physical	11	61	11	- 6
Mixed physical and mental	9	48	16	+ 6
Mental	24	54	13	- 1
All	44	55	14	- 1

* $P < 0.05$, ** $P < 0.01$.

Table 8. Musculoskeletal disability index of the men and women before and the mean change (+ = increased disability, - = decreased disability) after the follow-up by work content group.

Work content group	Number of subjects	Arbitrary units		
		Before follow-up		Change
		Mean	SD	
<i>Men</i>				
Physical	17	8.5	2.7	-1.2
Mixed physical and mental	12	6.8	2.5	+0.1
Mental	10	6.6	3.0	0.0
All	39	7.5	2.8	-0.5
<i>Women</i>				
Physical	11	7.5	3.9	+0.5
Mixed physical and mental	9	5.4	2.3	-0.5
Mental	24	6.3	3.4	+0.5
All	44	6.4	3.4	+0.3

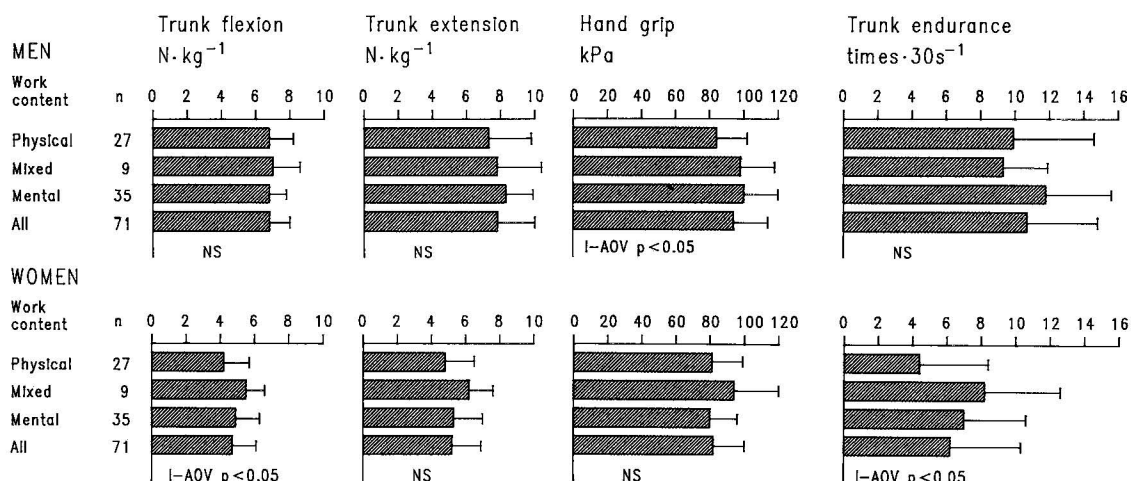


Figure 1. Maximal muscular strength and endurance of the men and women by work content group — means and 1 SD. (Mixed = mixed physical and mental work, 1-AOV = one-way analysis of variance, NS = not significant)

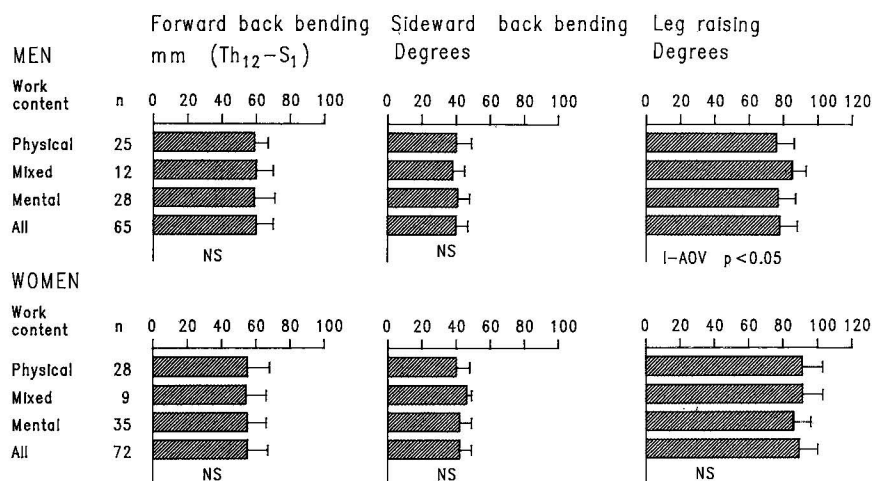


Figure 2. Joint mobility of the back and legs of the men and women by work content group — means and 1 SD. (Mixed = mixed mental and physical work, 1-AOV = one-way analysis of variance, NS = not significant)

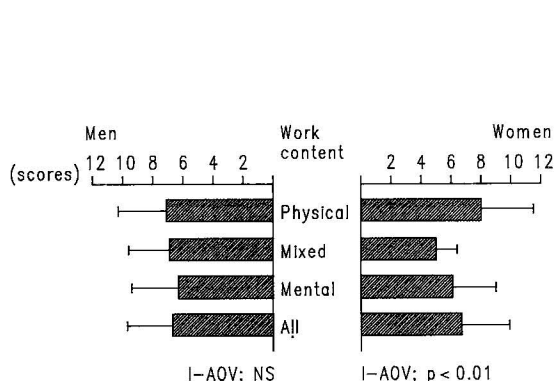


Figure 3. Musculoskeletal disability (index of 11 items) of the men and women by work content group — means and 1 SD. (Mixed = mixed physical and mental work, 1-AOV = one-way analysis of variance, NS = not significant)

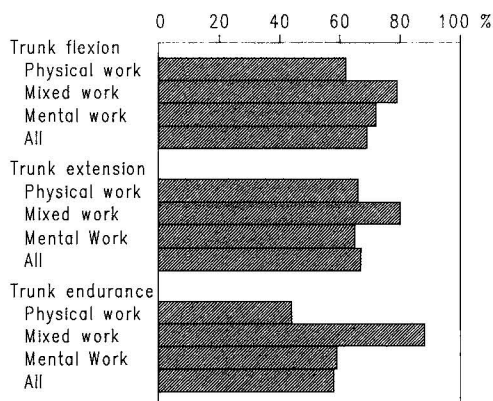


Figure 4. Trunk flexion, extension, and endurance strength of the women in relation to the men's (men = 100 %) by work content group. (Mixed work = mixed physical and mental work)

Cross-sectional study

Muscular strength. In the cross-sectional study in 1985 the three work content groups showed significant differences in the hand-grip strength of the men ($P < 0.01$) (figure 1). Those in physical work had the lowest and those in mental work the highest hand-grip strength. There were no significant differences in trunk strength among the men in the three groups.

Among the women there were significant differences between the three work groups in the maximal isometric strength of the trunk flexors ($P < 0.05$) and in trunk muscular endurance ($P < 0.05$) (figure 1). The women in mixed work had the highest values and those in physical work the lowest.

Mobility. There were no significant differences between the work groups in the bending of the back forward or sideward, either among the men or the women (figure 2). Among the men there were significant differences in the straight-leg raising test between the work groups ($P < 0.05$) (figure 2). Those in physical work had the poorest and those in mixed work the best results.

Musculoskeletal disability. Among the men there were no significant differences in musculoskeletal disability between the three work content groups (figure 3). Among the women the differences were significant between the three groups ($P < 0.01$), those in physical work having the most disability and those in mixed work the least.

Trunk strength of the women in relation to that of the men. At the mean age of 55 years the women's maximal isometric strength of the trunk flexors and extensors averaged 69 and 67 % of the men's, respectively (figure 4). The women's trunk muscular endurance was 58 % of the men's. The difference in trunk muscular endurance was greatest between the women and men in physical work, the women's being 44 % of the men's. The difference was smallest in the mixed work group, in which the women's muscular endurance reached 88 % of the men's.

Discussion

Follow-up study

The components of musculoskeletal capacity acted differently during the follow-up period. Maximal isometric muscular strength decreased, whereas trunk muscular endurance and back mobility increased. Musculoskeletal disability remained unchanged according to the used disability index. The changes were similar for all three work content groups.

A decrease in isometric muscular strength due to aging has been already observed in many studies

(3–7). On the assumption that the decrease in muscular strength is linear, two cross-sectional studies of men (7, 25) concluded that the decrease is between 0.6 to 1.2 % for trunk extension and between 0.3 and 0.9 % for trunk flexion annually after the age of about 30 years. The results of our longitudinal study showed a much greater decrease among older subjects. The calculated annual decrease for the women was 2.9 % for trunk extension strength and 2.6 % for trunk flexion strength. For the men the respective decreases were 4.4 and 6.1 %. Hand-grip strength has been shown to decrease annually from 0.5 % (3) and 0.8 % (5) to 1.1 % (7). In the present study the annual decrease in hand-grip strength among both the women and the men was 1.1 %. This rate of decline agrees well with the results of Viitasalo et al (7), but is higher than the results of Fisher & Birren (3) and Clement (5). The increase in trunk muscular endurance among the men was unexpected but could be explained by a learning or even a training effect, because sit-ups are easy to practice even at home. This kind of physical activity was not controlled among the subjects.

The calculations of annual relative change are open to question because some authors claim that the decline in muscular strength with age is not linear (6, 8). The results of the present study support the possibility of a nonlinear decline in trunk muscular strength that is greater than has been reported by, for example, Karvonen et al (25) and Viitasalo et al (7). The decline found in strength with age in longitudinal studies has been greater than that revealed in cross-sectional studies (5). Hand-grip strength, for example, was estimated to decline 60 % between the ages of 30 and 80 years in a longitudinal study, but only by 40 % in a cross-sectional study (5). This underestimation of strength loss with age by cross-sectional studies was assumed to be due to a natural selection effect which favors stronger individuals in elderly cohorts. In the present longitudinal study this phenomenon could partly explain the fact that the changes in muscular strength were greater than those that occurred in the earlier mentioned cross-sectional studies.

Another explanation for the relatively great decline in isometric strength could be the increased number of self-reported musculoskeletal diseases among the older subjects (26). During the follow-up period the occurrence of musculoskeletal diseases increased 14 % among both the women and the men. The prevalence of acute low-back symptoms was at about the same relatively high level during both measurements. It was especially high for the men (51 %). The impact of the musculoskeletal diseases and the low-back pain was obvious in the present study because muscular strength was systematically lower among those with a musculoskeletal disease or acute low-back pain in almost every test (26).

The increase found in spinal mobility during the follow-up period in the present study was in disagreement with the results of other studies (23, 27–29), in

which mobility has been shown to decrease with advancing age. Burton & Tillotson (29) found, however, an exception to this phenomenon. In their cross-sectional study of spinal mobility at different ages an increase in lower back mobility was found for the older men (> 54 years). There is no good explanation for this unexpected result.

The leisure-time physical activities of our subjects changed somewhat during the follow-up (26). The number of those who reported brisk physical activities one to two times a week decreased for the women and increased for the men. The increase in the number of physically active men supports the increase found in mobility and trunk muscular endurance among the men but seems in contrast to the great decline in isometric muscular strength. It is, however, difficult to estimate whether the brisk activity reported could have had any effect on musculoskeletal capacity because information on the types of activity was not obtained. Nevertheless, according to the results of the present study, the effects of aging and work on muscular strength are greater than the changes in physical activity during leisure time.

Cross-sectional study

The cross-sectional data showed that there were some significant differences in the musculoskeletal capacity of workers in different work content categories (physical, mental, and mixed work) and that those persons doing physical work had systematically the lowest capacity. This result is in agreement with the findings of other studies, in which the physical capacity of workers in jobs with heavy physical demands was lower than (1, 10, 12) or equal to (14) that of workers with mentally demanding jobs.

Decreased musculoskeletal capacity can be the combined result of prolonged physically demanding work and aging. This phenomenon was seen in the study by Heikkinen et al (1). They standardized both age and work and found that a cohort of physical workers aged 30–35 years had higher muscular strength than mental workers of the same age, but in a cohort aged 50–55 years the opposite was true, physical workers being inferior to mental workers in respect to muscular strength. The results of our study of 48- to 62-year-old physical workers support the finding of Heikkinen et al (1).

One explanation for the differences in musculoskeletal capacity between the groups with different work loads could be the occurrence of symptoms and diseases of the musculoskeletal system. The musculoskeletal capacity of the subjects was indeed systematically lower among those with a musculoskeletal disease or acute low-back pain (26).

Another explanation might be the leisure-time physical activities because physical capacity has been shown to be more related to physical activities during leisure time than to those during work (10, 30, 31). Sobolski

et al (32) showed, however, that physical capacity is very weakly related to the physical activity of middle-aged men with low occupational and leisure-time physical activity profiles. In the present study there were no significant differences in the prevalence of brisk physical activities during leisure time among the work groups (26). Therefore overall leisure-time physical activity does not seem to explain the differences in musculoskeletal capacity between the groups with different amounts of physical work.

Although the question of whether occupational work load has negative effects on musculoskeletal capacity is still open, there is increased evidence that occupational physical load has no training effects. This possibility is very understandable because the optimum pattern for training effects involves combinations of intensity, frequency, and duration which are not found under present work conditions. This conclusion is important to note because it contradicts the traditional view that physical effort during work maintains and increases physical capacity.

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