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Musculoskeletal capacity of employees aged 44 to 58 years in physical, mental and mixed types of work

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Summary. The musculoskeletal capacity of 60 women and 69 men, average age 52.3 ± 3.7 years was determined, including measurements of anthropometry, maximal isometric trunk flexion and extension, sit-ups, isometric hand grip strength and back mobility. According to the job and to cluster analysis, the subjects were divided into three dominating work groups; physical, mental, and mixed groups. The results showed significant differences in right hand grip strength of the women and in the number of sit-ups by men among the three work groups ($p < 0.05$). The differences between the other tests were not significant, although the physical group in the women and either the physical or the mixed group in the men had systematically the lowest mean values in almost all tests. It is concluded that jobs with mainly physical demands do not guarantee superior musculoskeletal capacity in older employees.

Key words: Age — Job analysis — Musculoskeletal capacity — Mental, mixed, and physical work

Introduction

There are few studies of the musculoskeletal capacity of older employees in different occupations. Available studies show controversial results. Yokomizo (1985) reported that white-collar workers perform equally well or slightly better than blue-collar workers in physical performance tests such as grasping power, vertical and horizontal jumping. Workers with vocational education seem to have greater muscle strength than unskilled workers (Mälkiä 1983). Older persons in higher managerial positions (50—55 years) have better muscle strength than manual labourers of the same age (Heikkinen et al. 1984). On the other hand, Kamon and Goldfuss (1978) found no differences in muscle strength among workers employed in jobs requiring different muscular strengths, and Kiiskinen et al. (1980) found that skilled manual workers doing heavy physical work had greater grip strengths than skilled manual workers doing lighter physical work. In earlier studies limited (e.g. Kamon and Goldfuss 1978) or no work analysis of the contents and demands of the jobs have been carried out. Careful work analysis is important when studying work-related aspects of any kind. A detailed analysis of the work and functional capacity of ageing employees is very important because the capacity of the worker declines with age although the work load usually does not decrease. This causes a greater relative strain on older employees than on younger ones (Ilmarinen and Rutenfranz 1980).

This laboratory study is part of a comprehensive multidisciplinary project aimed at finding criteria for retirement ages in municipal occupations in Finland. The study follows the stress and strain concept (Rutenfranz et al. 1976; Rohmert 1984), which hypothesised that individual characteristics (e.g. sex, age, functional capacity) control the relationship between work load and strain at work. In Finland, retirement ages are determined by job titles. Our project was intended to study whether the functional capacity of the worker could be one important feature to be included when setting new criteria for retirement ages. In the study cardiorespiratory, musculoskeletal and psychic functional capacities were assessed in laboratory conditions (Ilmarinen 1985). In the present report, the

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results of the measurement of musculoskeletal capacity of the workers, whose jobs were standardized according to their work content and demands, are analysed. The study included measurements of maximal isometric muscle strength, muscle endurance and spine mobility. Measurement of the musculoskeletal load at work in the same subjects has been reported earlier (Nygård et al. 1987).

Material and methods

Altogether 129 subjects, 60 women and 69 men, were chosen randomly from the response to a questionnaire on health, work ability and working environment (Ilmarinen 1985). All subjects had at least five years' experience in their jobs. The contents and demands of the jobs of all 129 subjects were analysed by the AET job analysis method (Landau 1978; Rohmert and Landau 1983). After observations at the workplace and interviews with the worker, jobs were analysed by means of 216 items concerning the tasks, equipment and environment, as well as the physical, psychic and social demands of the work. The jobs were then grouped by cluster analysis into 13 profile groups, and further into three groups according to the dominating work content (Ilmarinen 1985). The profile and job title groups in physical, mixed and mental work are summarized in Table 1. This study describes the results in the three dominating work content groups.

None of the subjects were on a sick-leave when attending the laboratory tests. The weight and height of the subjects in underwear and without shoes was measured and used for determination of the body mass index (weight/height^2) (Keys et al. 1972; Heliövaara 1980). The right triceps and subscapularis skinfolds were measured with a skinfold caliper (John Bull). The mean age, weight, height, body mass index and the sum of two skinfolds for the three work groups by sex are given in Table 2. The ages of the subjects ranged from 44—58 years. There were no significant differences in mean age, body weight, height, or body mass index between the three work groups, but among the women there were significant ($p < 0.01$) differences in the mean of the skinfolds between the three groups. The women in the mixed group had on average 17 to 18% thinner skinfolds than the mental and physical groups.

The maximal isometric muscle strength of the trunk flexors and extensors was measured by calibrated a dynamometer (Asmussen et al. 1959). The dynamometer consists of a frame with a strain gauge transducer (Philips Strain Gauge). The measurements were recorded on a chart recorder (Goerz Minigor 502). When measuring trunk flexion, the subject stood upright with his back against the dynamometer, being strapped tightly to the frame at the hips, and being attached to the strain gauge by a strap around his chest. The subject was asked to flex the trunk as hard as he could and hold it for 2—3 s. The researcher motivated the subject to make maximal exertions. The subject exerted two maximal contractions with a rest period of 30—60 s between them. The higher value was recorded as the maximal isometric strength value.The test was repeated in the same way for trunk extension with the subject standing facing the dynamometer.

The sit-up test (Nummi et al. 1978) was done to measure the dynamic endurance strength of the trunk flexors. The subject lay supine with the knees flexed at 90 degrees, the arms lying freely along the sides. The subject's feet were fixed to the table. He/she was then asked to rise to a sitting position, smoothly, without jerks and with rounded back, as many times as possible in 30 s.

Isometric hand grip strength was measured in both hands with a commercial, clinical device (Martin Vigorimeter). The device consisted of a rubber ball connected to a mechanical transducer with a readout. Two sizes of rubber ball were used, a smaller one for women and a larger one for men. The subjects performed two maximal hand grip exertions with each hand, of which the higher value was recorded.

The forward mobility of the whole back was assessed in the standing position by measuring how much the length of the spine between C_7 and S_1 increased when the back was bent forward with straight knees (American Academy of Orthopaedic Surgeons 1965).

Table 1. Cluster analysis[a] of work contents of 88 job titles classified into profile groups and into physical, mixed and mental work according to the dominating work content

Dominating work content	Profile groups	Job titles (examples)
Physical work	Auxiliary work	Garden worker, cleaner, construction worker, kitchen and hospital assistant, laborer, sanitation worker, street cleaner, street sweeper ($n = 16$ job titles)
	Installation work	Automobile mechanic, carpenter, electrician, fireman, janitor, machine mechanic, pipe fitter ($n = 13$)
	Domestic helper	Bather, domestic helper, housekeeper ($n = 3$)
Mixed work	Transport work	Bus driver, crane operator, excavator operator, loader operator, machine operator, tractor driver, truck driver ($n = 13$)
	Dump work	Caretaker at the dump site, dump worker ($n = 3$)
	Kitchen supervision	Cook ($n = 1$)
	Dental work	Dentist at a public health center ($n = 1$)
	Nursing work	Childcare worker, mental health nurse, nurse, practical nurse, specialized nurse ($n = 5$)
Mental work	Office work	Clerk, draftsman, map drawer, secretary, typist ($n = 8$)
	Adminstrative work	Department, bureau, or office supervisor, fire chief, head nurse, social secretary, social worker ($n = 15$)
	Technical supervision	Fire brigade foreman, supervisor at a construction site ($n = 3$)
	Physician's work	Ward physician ($n = 1$)
	Teaching	Daycare center teacher, trade teacher, vocational teacher ($n = 6$)

[a] see, e.g. Anderberg 1973

Table 2. Age, body weight, height, body mass index and sum of two skinfolds (triceps and subscapularis) by sex and work content (means and standard deviations)

	Physical work ($n=17$)	Mixed work ($n=17$)	Mental work ($n=26$)	All ($n=60$)
Women				
Age	53.0	50.6	52.3	52.3
(years)	± 3.1	± 3.2	± 4.1	± 3.7
Weight	69.9	66.8	67.6	68.3
(kg)	±17.7	± 6.4	±10.6	±12.7
Height	160.7	163.2	160.6	161.4
(cm)	± 7.8	± 4.5	± 4.9	± 5.8
Body mass index	26.0	25.0	26.3	26.0
($kg\ m^{-2}$)	± 4.8	± 2.2	± 4.2	± 3.9
Sum of skinfolds**	49	40	48	46
(mm)	±10	± 6	± 8	± 8
Men	($n=29$)	($n=23$)	($n=17$)	($n=69$)
Age	52.0	51.2	51.8	51.8
(years)	± 3.2	± 3.2	± 3.1	± 3.1
Weight	77.9	77.5	81.0	78.5
(kg)	±11.1	±10.9	± 7.9	±10.1
Height	174.9	173.7	175.4	174.7
(cm)	± 6.5	± 6.3	± 4.7	± 6.0
Body mass index	25.4	25.4	26.2	25.6
($kg\ m^{-2}$)	± 3.7	± 3.0	± 2.2	± 3.1
Sum of skinfolds	30	30	31	30
(mm)	± 8	± 6	± 4	± 6

** $p<0.01$ between the three work groups

Reliability and validity of the measurements

The job analyses with the AET method were carried out by trained researchers. The validity and reliability of this method have been discussed in detail by Rohmert and Landau (1979). In our study, five persons trained in AET classified nursing work, so that 75–89% of their classifications were in complete accord with the model classification.

The hand grip measuring device used in our study (Martin Vigorimeter) was validated by another device reported by Smolander et al. (1984), which comprised a rubber tube filled with water, and a pressure transducer connected to an indicator and a power supply. The coefficient of correlation between the results of the measurements with these two devices was 0.83 for the left and 0.86 for the right hand.

Twenty five subjects were retested within one month after the first measurements to test reliability. The coefficients of correlation between the first and second measurements were as follows; isometric trunk flexion ($r=0.82$) and extension ($r=0.84$), sit-ups ($r=0.71$), flexion mobility of whole spine (C_7-S_1) ($r=0.70$). Hand grip strength was retested in 14 subjects and the coefficient of correlation was 0.83 for the left hand and 0.93 for the right hand.

Statistical analysis

A one-way analysis of variance was used to test the differences in means between the three work groups. Pearson's correlation prodecure was used to calculate correlation coefficients in the test-retest situation.

Results

Among the women, statistically significant differences were found between the three dominating work groups in right hand grip strength ($p<0.05$) (Table 3). The lowest mean value, 76 kPa in physical work, was 18% lower than the highest, 93 kPa in mixed work. In the other strength tests, the physical work group had systematically but non-significantly the lowest mean values, and the mixed or mental groups had the highest mean values.

Among the men, there were significant differences in the number of sit-ups between the three work content groups ($p<0.05$) (Table 4). The lowest mean value was found in the physical work group, 7 in 30 s, and the highest in the mental work group, 11 in 30 s. The mental group often had the highest mean values, and the mixed or physical work groups the lowest mean values. The only exceptions were in trunk extension strength related to body weight, and left hand grip strength, in which the physical group had the same mean value as the mixed or the mental group. The standard deviations of the means were approximately at the same level in all work groups.

Table 3. Maximal isometric strength in trunk flexion and trunk extension (absolute and related to body weight), number of sit-ups, left and right hand grip strength and flexion mobility of the back of women by dominant work content

	Physical work ($n=17$) M ±SD	Mixed work ($n=17$) M ±SD	Mental work ($n=26$) M ±SD	All ($n=60$) M ±SD	1-AOV
Women					
Trunk flexion (N)	357 ±161	418[a] ±100	376 ±126	382[a] ±131	NS
Trunk flexion($N\ kg^{-1}$)	5.1 ± 2.1	6.2[a] ± 1.4	5.6 ± 1.8	5.6[a] ± 1.8	NS
Trunk extension (N)	368 ±186	424[a] ± 98	428 ±136	410[a] ±144	NS
Trunk extension ($N\ kg^{-1}$)	5.3 ± 2.5	6.3[a] ± 1.6	6.4 ± 2.0	6.1[a] ± 2.0	NS
Sit-ups (Numbers $30\ s^{-1}$)	4 ± 4	7 ± 3	6 ± 4	6 ± 4	NS
Left hand grip strength (kPa)	76 ± 24	86 ± 25	88 ± 17	84 ± 22	NS
Right hand grip strength (kPa)	76 ± 22	93 ± 20	86 ± 15	85 ± 19	*
Back mobility between C_7-S_1 (mm)	71 ± 17	70 ± 14	75 ± 19	72 ± 16	NS

NS = not significant
* = $p<0.05$
[a] $n=16$; one subject could not be measured because of acute back pain

Table 4. Maximal isometric strength in trunk flexion and trunk extension (absolute and related to body weight), number of sit-ups, left and right hand grip strength and flexion mobility of the back of women by dominant work content

	Physical work ($n=29$) M ±SD	Mixed work ($n=23$) M ±SD	Mental work ($n=17$) M ±SD	All ($n=69$) M ±SD	1-AOV
Men					
Trunk flexion (N)	694[a] ±170	663 ±202	724 ±162	691[a] ±165	NS
Trunk flexion ($N\ kg^{-1}$)	8.8[a] ± 1.8	8.7 ± 2.2	8.9 ± 1.5	8.8[a] ± 1.9	NS
Trunk extension (N)	739[a] ±193	719 ±183	744 ±223	733[a] ±195	NS
Trunk extension ($N\ kg^{-1}$)	9.4[a] ± 2.1	9.4 ± 2.5	9.1 ± 2.2	9.3[a] ± 2.3	NS
Sit-ups (numbers $30\ s^{-1}$)	7 ± 4	8 ± 3	11 ± 6	9 ± 5	*
Left hand grip strength (kPa)	99 ± 26	93 ± 23	99 ± 18	97 ± 23	NS
Right hand grip strength (kPa)	90 ± 24	97 ± 19	104 ± 21	96 ± 22	NS
Back mobility between C_7-S_1 (mm)	70 ± 16	69 ± 14	74 ± 10	70 ± 14	NS

NS = not significant
* = $p<0.05$
[a] $n=26$; three subjects could not be measured because of acute back pain

The isometric trunk flexion strength in the women averaged 55%, and related to body weight, 64% of men's flexion strength. For trunk extension, the corresponding values were 56% and 66%. Trunk extension strength in both women and men was approximately 6% greater than trunk flexion strength. Especially in isometric trunk strength, there was greater individual variation among women than among men. The differences in the standard deviations of the means between women and men were particularly marked in the physical work group.

Discussion

The study showed that women in physical work and men in either physical or mixed work had systematically the lowest capacity in all tests.

The trunk flexion strength results in our sample were 23% higher for women and 12% higher for men than those Asmussen and Heebøll-Nielsen (1961) reported when using the same type of dynamometer for a sample group of the same age and height. The trunk extension values, on the other hand, were 10% lower for women and 13% lower for men than those reported by Asmussen and Heebøll-Nielsen. In our study the male trunk flexion strength was at the same level as that reported by Heikkinen et al. (1984) for a cohort of men of the same age. However, trunk extension strength was 23% lower in our sample. The differences in mean strength corrected for body weight between our sample and that of Heikkinen et al. remained the same.

The mean number of sit-ups in our study was 6 for women and 9 for men, which is in good agreement with the values reported by Mälkiä (1983) who found mean values of 5 for women and 12 for men in a representative Finnish sample of the same age.

The results from different studies should be compared with caution, because many factors can influence such things as isometric strength measurements (Chaffin 1975). The reliability between the test-retest measurements in our study proved to be reasonable ($r = 0.82$–0.84). Alaranta et al. (1983) reported intra-observer correlation values from 0.83 to 0.97 and inter-observer correlations from 0.85 to 0.97 in a retest after one week with the same type of dynamometer as in our study.

It is interesting that our isometric trunk extension mean values are lower than those of Asmussen and Heebøll-Nielsen (1961) and Heikkinen et al. (1984). This can partly be explained by the fact that many of the subjects in our study had acute back symptoms. These symptoms could cause flexor overpowering in trunk strength (Pope et al. 1985). In our sample trunk flexion and extension strengths were almost at the same level. In contrast, trunk extension strength has been found to be 36–40% higher than trunk flexion in middle-aged subjects (Asmussen and Heebøll-Nielsen 1961; Heikkinen et al. 1984).

The employees in physically demanding jobs had the highest prevalence of musculoskeletal diseases and symptoms (Ilmarinen 1985). About 35% of the subjects in the present study had had some kind of back symptom during the seven days before the laboratory study, and the symptoms were most common among those in heavy physical work (Nygård, unpublished work). However, acute back symptoms correlated only weakly with the capacity tests. Earlier studies (Nachemson and Lind 1969) reveal decreased isometric muscle strength in both trunk extensors and flexors in patients with chronic back pain, immediately after sick leave of more than one month. All the subjects in our sample were at work during the laboratory study, so the symptoms were not too serious to prevent the workers from doing the capacity tests. Although correlation of the test results with acute back symptoms was low, it was negative for the strength tests. This means that the symptoms do affect strength to some degree. Thus the symptoms and diseases of the musculoskeletal system could partly explain the differences in musculoskeletal capacity between the work groups.

The isometric trunk strength of the women was 55–66% that of the men, which is in good agreement with the values reported by Laubach (1976). The differences in muscle strength between men and women are noteworthy, because the women doing physical work (e.g. auxiliary work) in this study had the same musculoskeletal load at work as the men (Nygård et al. 1987). This imbalance of high load and low capacity can lead to higher strain among women than among men doing the same work. In fact, the women in this study had more bad working postures (Nygård 1986) and higher mean heart rates at work than the men (Ilmarinen 1985). Also the prevalence of musculoskeletal diseases in the entire sample in the retirement age study ($n = 6268$; Ilmarinen 1985) was 3% higher for women than for men at age 50 years (39.4 and 36.4 respectively), which to some degree might be due to the higher strain at work and lower capacity of the women than of the men. Those in mentally demanding jobs had the same or even better muscle strength than those in physical jobs. This finding agrees with those of Heikkinen et al. (1984), Yokomizo (1985) and Mälkiä (1983). In younger workers the opposite seems to be true (Heikkinen et al. 1984), physical workers being superior to mental workers in muscle strength. The higher the muscle strength of young workers, the greater will be the expected decrease due to the negative effects of prolonged physical work, as found in maximal aerobic power (Ilmarinen and Rutenfranz 1980).

The reason why persons who have a physically heavy job do not have superior functional capacity, compared to those with a physically light job, is unknown. One explanation might lie in leisure-time physical activities, because physical capacity is more related to physical activities in leisure time than at work (Mälkiä 1983; Haglund 1984; Tuxworth et al. 1986) and particularly in relatively heavy strenuous physical activities (Tuxworth et al. 1986). In a study of leisure-time activities among a representative Finnish sample aged between 18—54 years (Vuori and Sievers 1978), per sons in mentally demanding jobs were found to be physically more active in their leisure time than those doing physically heavy occupational work. In contrast, Cunningham et al. (1969) found no clear differences between blue-collar and white-collar workers in regard to leisure time activities. In the present study there were also no significant differences in the prevalence of brisk physical activities in leisure time (48.5% of the mental, 43% of the physical and 38% of the mixed workers, respectively). Conversely, the women in mixed work were least active (29.5%) but had a high functional capacity. So leisure time physical activitiy does not seem to explain the differences in musculoskeletal capacity between the work content groups in our sample.

In spite of the fact that all the physical workers in the present study did significantly heavier physical work than the mental and mixed workers (Ilmarinen 1985), the work load did not have any training effects on the maximal musculoskeletal capacity of the workers. This is understandable when the content of physical work is considered: it does not include that optimal combination of intensity, frequency and duration needed for training effects.

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