

Changes in maximal cardiorespiratory capacity among aging municipal employees

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ILMARINEN J, LOUHEVAARA V, KORHONEN O, NYGÅRD C-H, HAKOLA T, SUVANTO S. Changes in maximal cardiorespiratory capacity among aging municipal employees. *Scand J Work Environ Health* 1991;17(suppl 1):99–109. Before and after a four-year follow-up, maximal oxygen consumption ($\dot{V}O_{2\max}$) was determined for 67 municipal employees (initial age about 51 years). The $\dot{V}O_{2\max}$ ($\text{ml} \cdot \text{kg}^{-1}$) decreased 6 % among the women and increased 8 % among the men, the greatest and smallest change occurring for employees doing mental and physical work, respectively. The men's increase was associated with an increase in leisure-time physical activity. Work content was not associated with the level of $\dot{V}O_{2\max}$ for either gender. After the four years the women's absolute $\dot{V}O_{2\max}$ was about 66 % of the men's. There were marked changes in $\dot{V}O_{2\max}$ at the individual level, the most marked decreases being associated with the use of medication in some cases. After the four years the women's $\dot{V}O_{2\max}$ of 63 % was insufficient according to current recommendations. Therefore physically demanding jobs are not generally recommended for older women.

Key terms: aging, maximal oxygen consumption, medication, physical activity, work content.

According to the stress-strain concept, in heavy dynamic physical work, maximal cardiorespiratory capacity determines the level of strain. The better the maximal oxygen consumption ($\dot{V}O_{2\max}$), the lower the cardiorespiratory strain at a given work load (1, 2).

Today, various occupations still include physical demands even though the content of the physical load has changed. The muscular work load is more static than dynamic and more one-sided than earlier. It has been estimated that about 20–25 % of occupational work in industrialized countries will stay physically strenuous because the tasks cannot be replaced by technological advancements or automation (3). Recent field studies have indicated that the aerobic demands of work in different countries often exceeds, on the average, 1.0 l of oxygen $\cdot \text{min}^{-1}$, whereas the heaviest tasks and peak loads exceed 2.0 l of oxygen $\cdot \text{min}^{-1}$ (4).

In Finnish municipal occupations the relative aerobic strain has been shown to vary from 9 to 90 % of the $\dot{V}O_{2\max}$ due to the marked differences in individual $\dot{V}O_{2\max}$ values (5). It is obvious that the level of $\dot{V}O_{2\max}$ for physical work becomes critical when age-related decreases in $\dot{V}O_{2\max}$ occur. An insufficiency of $\dot{V}O_{2\max}$ for work is also due to the unchanged physical demands of work during aging. It should be mentioned also that an increase in the prevalence rates of diseases during aging is common among aging municipal employees (6).

The objective of this study was to determine the changes in maximal cardiorespiratory capacity among aging workers who did not change jobs during a follow-up period of four years. We were interested in studying whether the changes were similar for persons doing physical, mental, and mixed physical and mental work. Special attention was given to individual changes related to leisure-time physical activity and the use of medication.

Subjects and methods

The subjects were 67 men and women who continued in the same job during the four-year follow-up period. After the follow-up the mean age of the men was 54.9 years, and that of the women was 54.8 years. The differences in the mean age of the workers in the three work content groups (physical, mental, and mixed physical and mental) were not statistically significant. Neither were the gender differences in height, body weight, lean body mass, or percentage of fat (table 1).

Before the exercise test the subjects were medically examined, and the use of medication was checked. Leisure-time activities during the previous year were recorded.

A submaximal exercise test was carried out on a calibrated, mechanically braked cycle ergometer (Monark, Monark A/S, Sweden). The continuous test started with a warm-up period of 3 min with an external work load of 50 W. The warm-up was followed by three to five stepwise increasing work loads. The increases in work load corresponded to 25 or 50 W depending on the individual heart rate (HR) response. The pedaling rate of 50 revolutions $\cdot \text{min}^{-1}$ was paced

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Table 1. Mean age and anthropometric characteristics of the men and women in the physical, mixed physical and mental, and mental work groups before and after the follow-up.

Work content group	Characteristic									
	Age (years)		Height (cm)		Weight (kg)		Lean body mass (kg)		Fat (%)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Physical										
Men (N = 14)										
Before	51.9	3.0	175.8	7.7	77.5	10.3	60.1	7.2	22.0	6.3
After	55.5	2.9	175.3	7.4	78.6	11.8	61.7	8.2	21.1	6.3
Women (N = 9)										
Before	52.6	3.0	159.0	7.8	63.2	9.5	42.2	4.9	32.6	7.9
After	56.3	2.9	158.0	8.0	64.4	4.9	44.6	5.3	30.2	7.0
Mixed physical and mental										
Men (N = 9)										
Before	49.5	2.9	173.1	6.1	72.6	9.0	57.6	5.9	20.2	5.2
After	53.0	3.1	172.6	6.2	73.6	8.9	58.6	5.8	20.1	4.5
Women (N = 7)										
Before	48.8	2.1	162.2	5.0	67.7	4.9	44.7	3.8	33.7	6.7
After	52.4	2.8	161.8	5.5	68.7	6.6	47.2	3.0	30.7	7.3
Mental										
Men (N = 9)										
Before	52.2	2.7	175.0	5.0	81.3	8.3	60.4	4.6	25.3	5.3
After	55.8	2.8	174.2	6.5	81.0	8.7	62.8	6.8	22.3	3.5
Women (N = 19)										
Before	51.4	4.0	160.7	5.1	67.8	11.1	43.2	5.4	35.4	8.2
After	54.9	4.0	160.2	4.9	69.6	11.0	44.9	4.8	34.7	9.3
All										
Men (N = 32)										
Before	51.3	3.0	175.1	6.6	77.2	9.8	59.5	6.1	22.4	5.9
After	54.9	3.1	174.2	6.8	77.9	10.4	61.1	7.2	21.1	5.1
Women (N = 35)										
Before	51.2	3.6	160.5	5.9	66.5	9.5	43.2	5.0	34.3	7.7
After	54.8	3.6	159.9	6.0	68.0	9.9	45.2	4.7	32.7	8.4

Table 2. Comparison of the submaximal and maximal cycle ergometer test before and after the follow-up. (HRmax = maximal heart rate, $\dot{V}O_{2\max}$ = maximal oxygen consumption)

	Variable											
	HRmax (min^{-1})			$\dot{V}O_{2\max}$ (l min^{-1})			$\dot{V}O_{2\max}$ ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)			Maximal work output (W)		
	Mean	SD	Difference (%) ^a	Mean	SD	Difference (%) ^a	Mean	SD	Difference (%) ^a	Mean	SD	Difference (%) ^a
Before follow-up (N = 19)												
Submaximal test	167.3	2.6	0.0	2.21	0.60	-0.6	30.4	5.1	-6.7	154.5	4.8	-13.4
Maximal test	167.3	11.2		2.36	0.58		32.6	4.9		178.2	47.6	
After follow-up (N = 14)												
Submaximal test	165.4	2.9	-1.3	2.34	0.51	-9.7	31.5	4.7	-10.0	164.0	41.6	-20.8
Maximal test	167.6	9.0		2.59	0.81		35.0	10.1		207.1	77.6	

^a (submax - max/max) $\times$ 100.

by a metronome and registered (Printina, Misuratory Electronici, Italy). The test was terminated when about 85 % of the predicted maximal heart rate was achieved. At each work load the subject pedaled at least 4 min or until a steady-state heart rate was reached. In the tests before and after the follow-up the equal individual work loads were used. Before, during, and after the

test an electrocardiogram was recorded (Mingograf 34, Siemens-Elema, Germany). The heart rates for the prediction of $\dot{V}O_{2\max}$ were calculated from 15 successive QRS intervals of the electrocardiogram. During the tests the respiratory frequency, tidal volume, pulmonary ventilation, oxygen uptake, carbon dioxide output, and respiratory exchange ratio were continu-

ously measured and automatically printed by a microprocessor-controlled respiratory gas exchange analyzer (Morgan Exercise Test System, PK Morgan Ltd, United Kingdom and Mijnhard Oxycon-4, Gebr Mijnhardt BV, The Netherlands) (7). A linear regression equation was fitted through $\dot{V}O_2$ plottings, and its cut-off point with the predicted maximal heart rate was considered the reference for the $\dot{V}O_{2\max}$. For the maximal heart rate (HRmax) the following equation was used (8):

$$\text{HRmax} = 210 - 0.8 (\text{age}).$$

A second test was carried out for those subjects who had no contraindications for a maximal exercise test. Altogether 19 and 14 subjects successfully performed the maximal test protocol before and after the follow-up, respectively.

For evaluating the reliability of the submaximal exercise test, we compared the results of the submaximal and maximal tests of the same subjects. The measured maximal heart rate was very near the predicted values before and after the follow-up (table 2). The $\dot{V}O_{2\max}$ was underestimated by the submaximal test, by about 6 % before and about 9 % after the follow-up on the average. In terms of maximal external work output in watts, the underestimation of the submaximal tests was 13 % before and 21 % after the follow-up (table 2).

Regular medication was classified as follows: a beta-blocking drug, a beta-blocking drug plus another antihypertensive agent, a beta-blocking drug plus digitalis, a beta-blocking drug plus another antihypertensive agent plus digitalis, some hypertensive agent (other than a beta-blocking drug), some hypertensive agent (other than a beta-blocking drug) plus digitalis, digitalis, and some other form of medication.

The subject's physical activity during the year before the exercise tests was assessed from the responses to a questionnaire. (See reference 6.) The changes in

physical activity level were also inquired about before the exercise test after the follow-up. In the questionnaires the query on physical activity was stated as "How often did you participate in physical activity on the average during the past year? Physical activity is defined as a sport, exercise, training, or heavy leisure activity which lasts at least 15–20 min per session and causes accelerated breathing." The frequency of such activities was classified in the following way: (i) strenuous activity at least twice a week, (ii) strenuous activity at least once a week, (iii) some activity once a week, (iv) some activity less often than once a week, and (v) no such activity at all. For the comparison of the activity levels before and after the follow-up the changes were rated on the following scale: 0 = no change in the activity level, 1 = change one class (increase or decrease), 2 = change two classes (increase or decrease), and 3 = change three classes (increase or decrease).

Results

Changes in maximal cardiorespiratory capacity according to work content group

Among the men the $\dot{V}O_{2\max}$ and maximal work output increased in all the work content groups (table 3). The increase was greatest in the mental work group, where the $\dot{V}O_{2\max}$ increased $0.27 \text{ l} \cdot \text{min}^{-1}$ or $3.6 \text{ ml} \cdot \text{kg}^{-1}$ of body weight ($P < 0.05$). The maximal work load increased 22.5 W. The increase was the smallest in the physical work group. The increase in $\dot{V}O_{2\max}$ among the men was, on the average, 8 %.

Among the women an opposite change was found. The maximal physical work capacity decreased in all the work content groups (table 4). The largest decrease was found in the mental work group, where the $\dot{V}O_{2\max}$ related to body weight decreased 9 % ($P < 0.05$). The decrease was smallest in the physical work group. Among the women the decrease in abso-

Table 3. Maximal oxygen consumption ($\dot{V}O_{2\max}$) and maximal work output of the men before the follow-up [mean age 51.3 (SD 3) years] and the change after the follow-up [mean age 54.9 (SD 3) years] according to work content group.

Work content group	$\dot{V}O_{2\max}$ ($\text{l} \cdot \text{min}^{-1}$)		$\dot{V}O_{2\max}$ ($\text{ml} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$)		Maximal work output (W)	
	Mean	SD	Mean	SD	Mean	SD
Physical (N = 14)						
Before	2.76	0.58	35.7	6.2	199.1	46.9
Change after	+ 0.0	0.55	+ 0.4	7.6	+ 4.2	44.7
Mixed physical and mental (N = 9)						
Before	2.71	0.46	37.5	6.1	196.5	38.4
Change after	+ 0.21	0.52	+ 2.4	7.2	+ 15.5	43.6
Mental (N = 9)						
Before	2.62	0.63	31.8	6.6	187.4	51.5
Change after	+ 0.27	0.39	+ 3.6*	4.6	+ 22.5	31.6
All (N = 32)						
Before	2.71	0.54	35.2	6.5	195.1	44.7
Change after	+ 0.16	0.50	+ 1.9*	6.7	+ 12.5	40.6

* $P < 0.05$.

Table 4. Maximal oxygen consumption ($\dot{V}O_{2\max}$) and maximal work output of the women before the follow-up [mean age 51.2 (SD 3.6) years] and the change after the follow-up [mean age 54.8 (SD 3.6) years] according to work content group.

Work content group	$\dot{V}O_{2\max}$ ($l \cdot \min^{-1}$)		$\dot{V}O_{2\max}$ ($ml \cdot \min^{-1} \cdot kg^{-1}$)		Maximal work output (W)	
	Mean	SD	Mean	SD	Mean	SD
Physical (N = 9)						
Before	1.72	0.45	28.1	6.5	114.1	37.1
Change after	-0.03	0.47	-1.2	7.2	-3.5	39.2
Mixed physical and mental (N = 7)						
Before	1.98	0.28	29.1	5.8	134.7	23.2
Change after	-0.09	0.35	-2.2	5.1	-7.9	28.9
Mental (N = 19)						
Before	1.88	0.38	28.2	5.8	127.2	31.2
Change after	-0.13	0.28	-2.5*	4.0	-11.0	23.4
All (N = 35)						
Before	1.86	0.38	28.4	5.8	125.4	31.4
Change after	-1.10	0.35	-2.1*	5.1	-8.5	28.5

* $P < 0.05$.

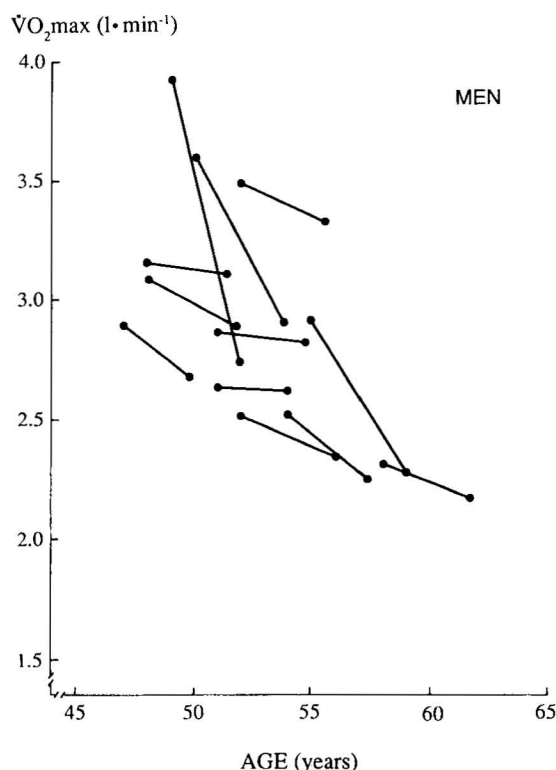


Figure 1. Decline in the absolute maximal oxygen consumption ($\dot{V}O_{2\max}$) of 12 men in four years after the age of 45 years.

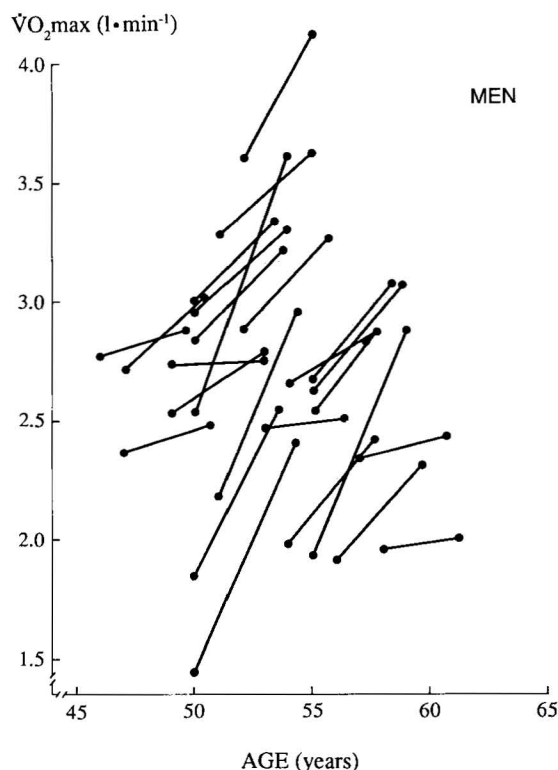


Figure 2. Improvement in the absolute maximal oxygen consumption ($\dot{V}O_{2\max}$) of 26 men in four years after the age of 45 years.

lute $\dot{V}O_{2\max}$ averaged 3 %, and the decrease in relation to body weight was 6 %.

Individual changes in maximal oxygen consumption

Among the men the $\dot{V}O_{2\max}$ decreased in 12 subjects (32 %). Two men had a decrease of about 0.5

$l \cdot \min^{-1}$, but one subject had a marked decrease of over $1.0 l \cdot \min^{-1}$ (figure 1). Most of the men had increased their maximal aerobic capacity (68 %). Three of them had an increase of over $1.0 l \cdot \min^{-1}$, and many of the men had an improvement of over $0.5 l \cdot \min^{-1}$ (figure 2). The absolute $\dot{V}O_{2\max}$ decreased during the four years among 23 women (59 %). In general, the decrease was less than $0.5 l \cdot \min^{-1}$,

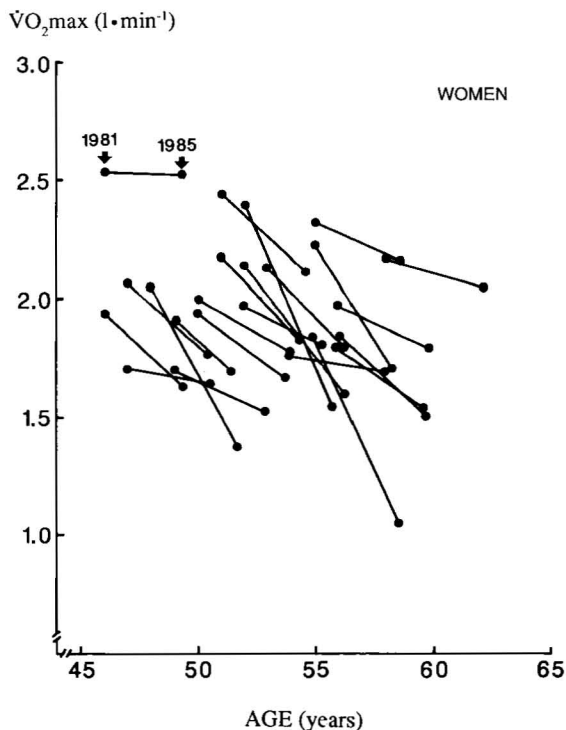


Figure 3. Decline in the absolute maximal oxygen consumption ($\dot{V}O_{2\max}$) of 23 women in four years after the age of 45 years.

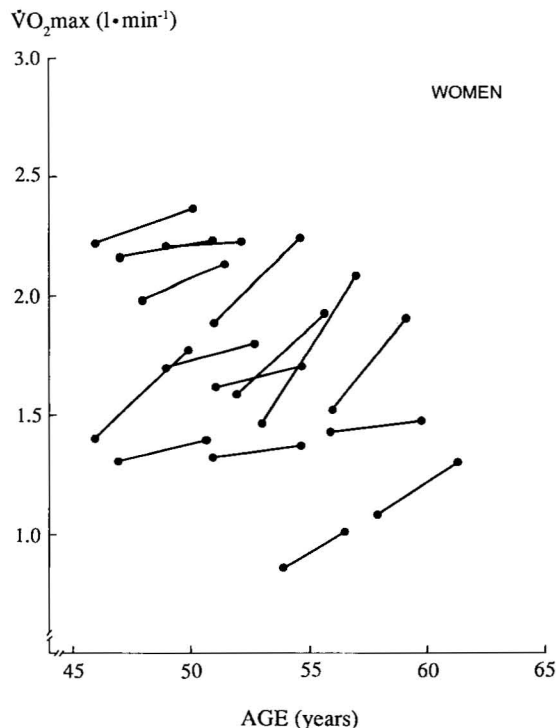


Figure 4. Improvement in the absolute maximal oxygen consumption ($\dot{V}O_{2\max}$) of 16 women in four years after the age of 45 years.

but for two subjects it was about $1.0 \text{ l} \cdot \text{min}^{-1}$ (figure 3). For 16 women (41 %) the $\dot{V}O_{2\max}$ in liters per minute increased during the four years. Five of them had an increase of about $0.5 \text{ l} \cdot \text{min}^{-1}$; the others showed less improvement (figure 4). Neither the decrease nor the increase in $\dot{V}O_{2\max}$ was systematically related to age among the men or the women.

Individual changes in maximal oxygen consumption in relation to the use of medication

For three of the four men who had a marked decrease ($>0.5 \text{ l} \cdot \text{min}^{-1}$) in their $\dot{V}O_{2\max}$, medication was started during the follow-up. Those men who had the highest increase in $\dot{V}O_{2\max}$ did not use any medication. The marked improvement ($>0.5 \text{ l} \cdot \text{min}^{-1}$) in $\dot{V}O_{2\max}$ was related to the lower base-line level (figure 5).

The decrease in $\dot{V}O_{2\max}$ was combined with medication for eight women (35 %). For three women with a decrease of over $0.5 \text{ l} \cdot \text{min}^{-1}$, some medication for hypertension was started, in addition to a beta-blocking agent, during the follow-up. Two women without any medication had a decrease in $\dot{V}O_{2\max}$ of over $0.5 \text{ l} \cdot \text{min}^{-1}$ in the four-year follow-up. The $\dot{V}O_{2\max}$ had increased the most often among the women with a low base-line level, independently of medication. The improvements, however, were less than $0.5 \text{ l} \cdot \text{min}^{-1}$ (figure 6).

Individual changes in maximal oxygen consumption in relation to the changes in physical activity level

For three out of four men a marked decrease in $\dot{V}O_{2\max}$ was associated with a decrease in physical activity level. A marked increase in $\dot{V}O_{2\max}$ was not always combined with reports of increased physical activity, however. An increase of over $0.5 \text{ l} \cdot \text{min}^{-1}$ was found for four men who reported no changes in physical activity level (figure 7). Among the women the reported changes in physical activity level were not associated with the changes in $\dot{V}O_{2\max}$ (figure 8).

Gender differences in maximal oxygen consumption according to work content group

The absolute $\dot{V}O_{2\max}$ of the women was about 69 and 64 % of that of the men at the ages of 51 and 55 years, respectively (figure 9). At the age of 51 years the women's absolute value was the lowest in the physical work group (62 %) and the highest in the mental work group (73 %) compared with the men's values. Four years later the women's best was measured in the physical work group (66 %), and their lowest occurred in the mental work group (62 %) in comparison with the men's results. The women's $\dot{V}O_{2\max}$ in relation to body weight was about 81 and 73 % of that of the men at the ages of 51 and 55 years, respectively. The women's highest $\dot{V}O_{2\max}$, compared with that of the men at 51 years of age, was found for the mental

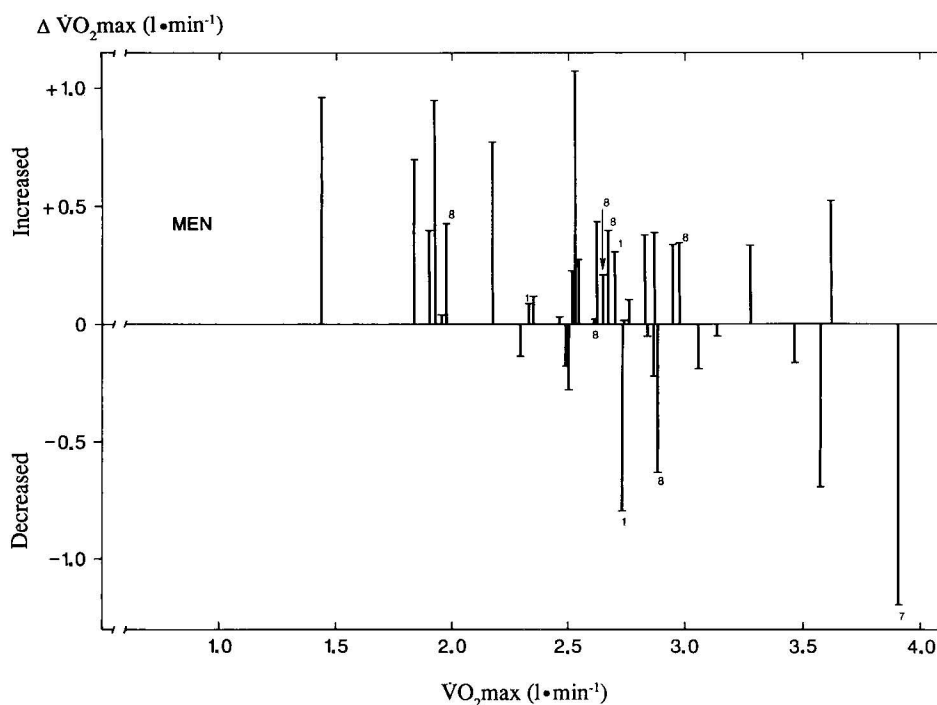


Figure 5. Individual changes in the absolute maximal oxygen consumption ($\dot{V}O_{2\max}$) in relation to the base-line level of $\dot{V}O_{2\max}$ and the use of regular medication among the men in four years (1 = beta-blocking drug, 7 = digitalis, 8 = some other form of medication).

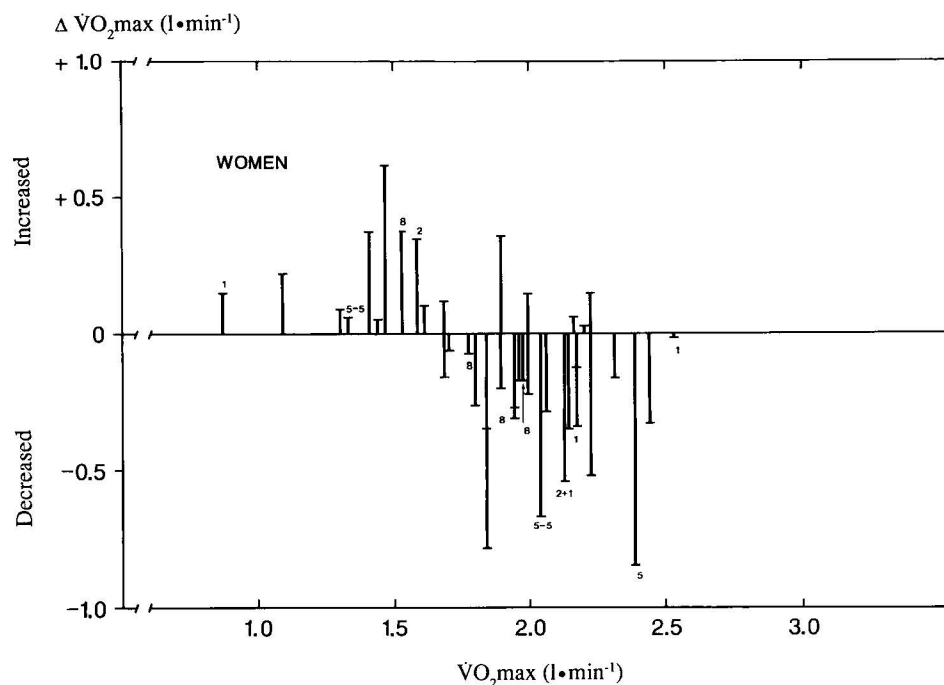


Figure 6. Individual changes in the absolute maximal oxygen consumption ($\dot{V}O_{2\max}$) in relation to the base-line level of $\dot{V}O_{2\max}$ and to the use of medication among the women in four years (1 = beta-blocking drug, 2 = beta-blocking drug plus another anti-hypertensive agent, 5 = some other hypertensive agent than a beta-blocking drug, 8 = some other form of medication. 2 + 1 = antihypertensive drug since base line and beta-blocking during the follow-up period, 5 – 5 = some other hypertensive agent than a beta-blocking agent since base line, which continues).

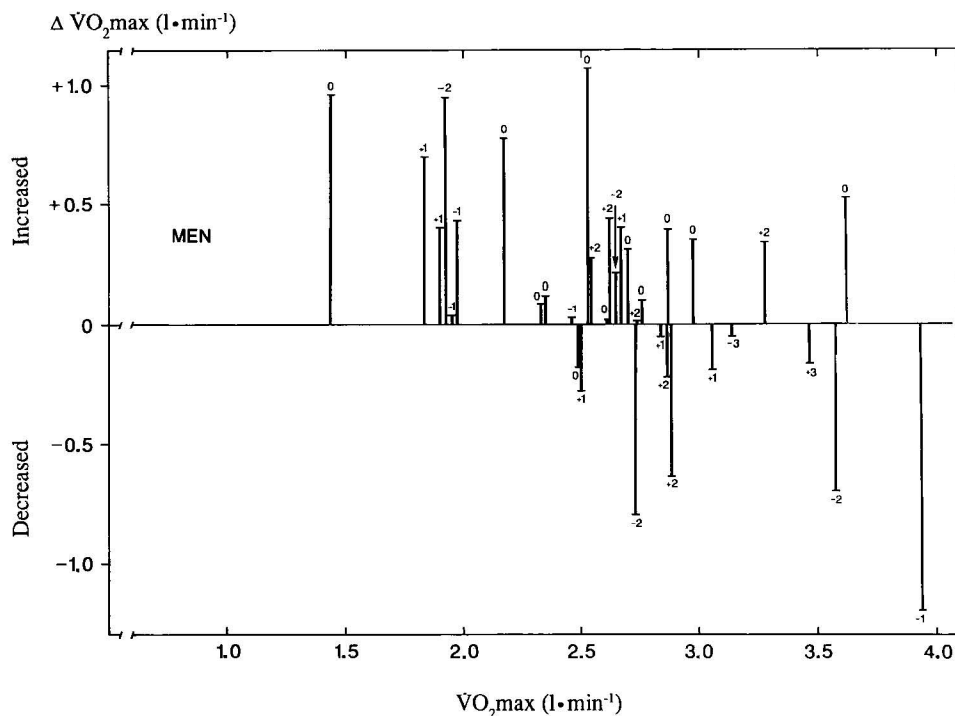


Figure 7. Individual changes in absolute maximal oxygen consumption (VO_2max) in relation to the base-line level of VO_2max and to the changes in physical activity level in four years among the men. (0 = no change in the activity level, 1 = change one class (plus = increase, minus = decrease), 2 = change two classes, and 3 = change three classes)

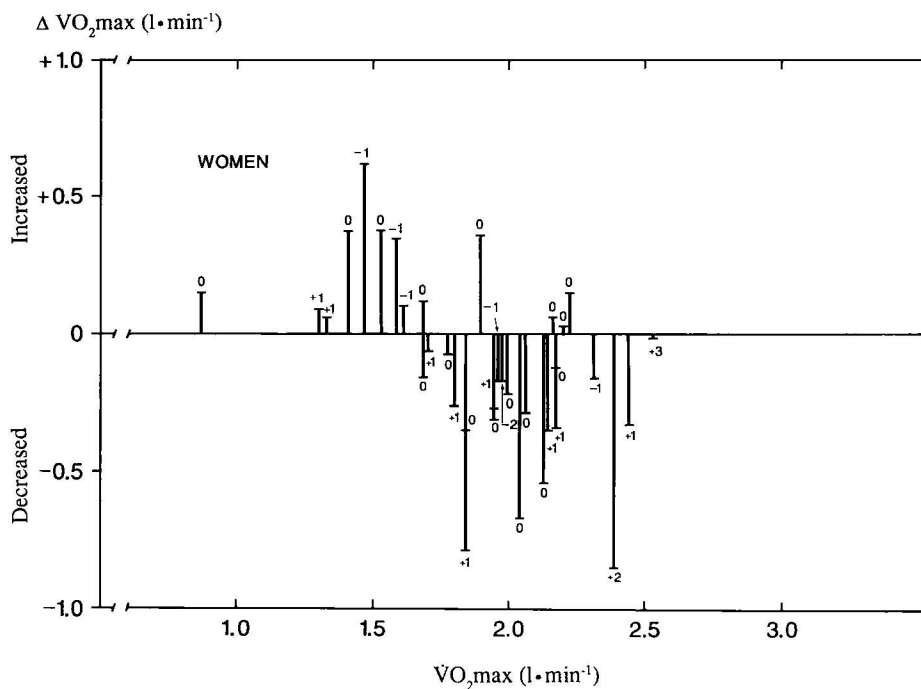


Figure 8. Individual changes in absolute maximal oxygen consumption (VO_2max) in relation to the base-line level of VO_2max and to the changes in physical activity level in four years among the women. (0 = no change in the activity level, 1 = change one class (plus = increase, minus = decrease), 2 = change two classes, and 3 = change three classes)

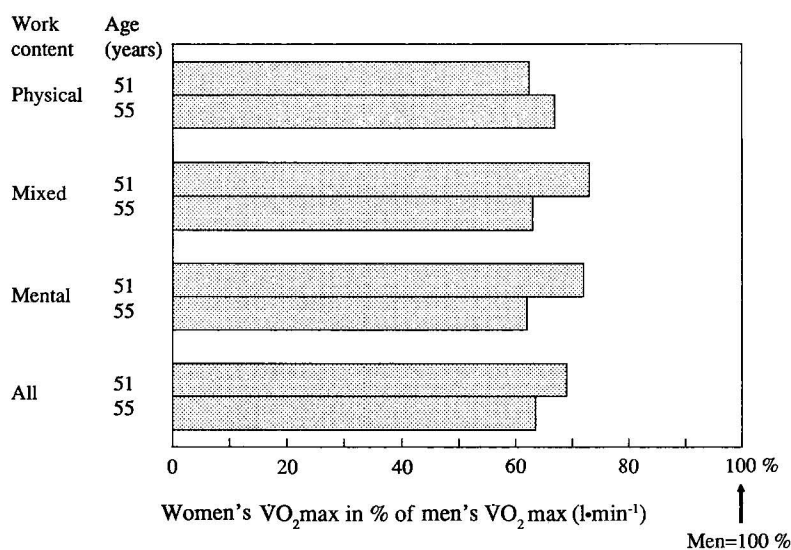


Figure 9. Gender differences in absolute maximal oxygen consumption ($\dot{V}O_2\text{max}$) at age 51 and 55 years according to work content group.

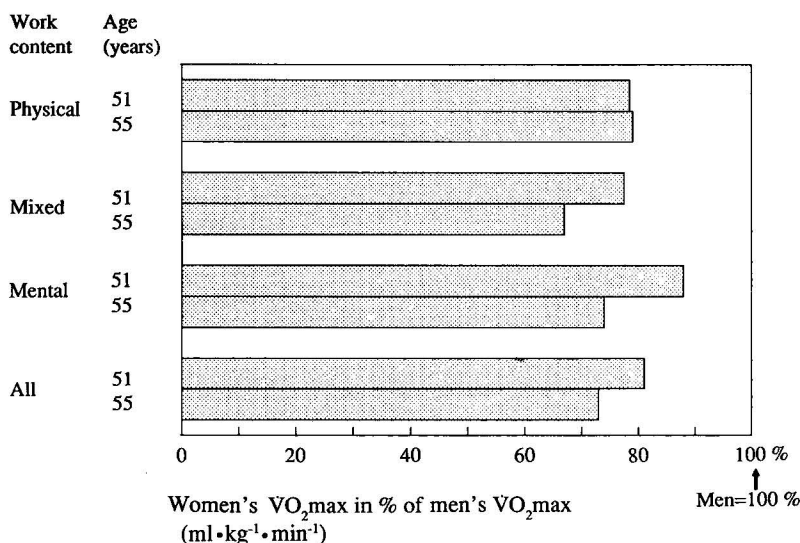


Figure 10. Gender differences in maximal oxygen consumption ($\dot{V}O_2\text{max}$) in relation to body weight at the age of 51 and 55 years according to work content group.

work group (89 %), and their lowest was determined for the mixed physical and mental work group (78 %). Four years later, the women's lowest was found again for the mixed work group (67 %), but the best was determined for the physical work group (80 %) (figure 10). In the physical work groups, the differences between the men and the women before and after the follow-up were practically unchanged.

Discussion

Maximal cardiorespiratory capacity

The differences in the subjects' $\dot{V}O_2\text{max}$ between the physical, mental, and mixed work groups were small at the ages of both 51 and 55 years. The only exception was the men, at 55 years of age, who were

doing mixed work (eg, bus drivers). They had a higher $\dot{V}O_2\text{max}$ ($40.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{body weight}^{-1}$) than the men doing physical or mental work ($35.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{body weight}^{-1}$). This finding may support the idea that a combination of physical and mental demands at work is better for protecting against a decrease in $\dot{V}O_2\text{max}$ than one-sided static physical load or physical inactivity. On the other hand, the men doing mixed work were about two years younger than the others, and 80 % of them did not use any medication for coronary heart disease.

The results of the similarity of cardiorespiratory capacity among the work content groups at the age of 55 years supported those obtained at the age of 51 years. A similar finding has also been reported for German men at the age of 41 years (9). It is obvious that the $\dot{V}O_2\text{max}$ is on the same level after the age of

40 years in different occupational groups. Our results for musculoskeletal capacity were similar. (See reference 10.) Even if the qualification for physically demanding occupations at a young age is based on a higher physical work capacity, this superiority is no longer apparent after the age of 40 years. In physical occupations also those having a lower than an average capacity continue to work towards an old-age pension. In our material, at the age of 55 years, 41 % of the women and 38 % of the men in physically demanding occupations had a lower absolute $\dot{V}O_{2\max}$ than the average level.

The differences in $\dot{V}O_{2\max}$ between the older men and women was marked. Oxygen consumption at work should be at least 20 % lower for women than for men after the age of 50 years if the relative aerobic strain is to be the same for women and men. Therefore, critical statements against the suitability of older women for physical work have been issued (11). Although every fourth woman at the age of 51 years has a $\dot{V}O_{2\max}$ similar to that of men the same age, the level of absolute $\dot{V}O_{2\max}$ needed is typical for only 1–2 % of women aged 51 years. For example, the level needed for construction work is $2.75 \text{ l} \cdot \text{min}^{-1}$.

The decrease in $\dot{V}O_{2\max}$ at the group level was 3–6 % for our female subjects in the four-year follow-up. This finding is similar to that reported between the age groups of 51 and 55 years at the population level (12). Finnish women had, at 55 years of age, about the same absolute and relative $\dot{V}O_{2\max}$ as Czech women (12).

The average increase in $\dot{V}O_{2\max}$ among the men of our study was 8 % in four years. Therefore, the level of the male municipal employees in our study was better at 55 years of age than that of Czech men (12), and also better than another group of Finnish men (13). German men who were more than 10 years younger had the same level of $\dot{V}O_{2\max}$ as the Finnish men in municipal occupations at the age of 53 years (9). Normally, $\dot{V}O_{2\max}$ decreases with age (14, 15, 16), but also improvements can be achieved after the age of 50 years, as indicated by our data.

Leisure-time physical activity

The change in physical activity habits among the men (increase) and women (decrease) explains the change in $\dot{V}O_{2\max}$ during the four-year follow-up at the group level. Strenuous activity at least once a week increased among the men from 40 to 56 %. In the mixed work group this increase was from 40 to 63 %, and in mental work it was from 40 to 60 %. In the latter group the absolute $\dot{V}O_{2\max}$ improved the most (ie, 10 %). Before the follow-up the municipal employees in our study were as active as Finnish men and women on the average at the age of 50–54 years (17), but they were more active than subjects in an east Finland population (18). The five-class scale used for the physical activity assessment did not include information on the

quality of the leisure-time activities. The interview before the exercise test indicated, however, that the men mostly jogged, skied, cycled, and swam, whereas the women preferred brisk walking. The compatibility between the changes in physical activity and $\dot{V}O_{2\max}$ was not optimal in our study because the questionnaire data were gathered 3–12 months before the exercise test data. This is probably the reason why the changes in fitness and physical activity did not correspond well at the individual level.

Use of medication

It is known that beta-blocking drugs increase muscle fatigue in short-term exercise and decrease physical work capacity in long-term exercise (19). Such medication makes the assessment of $\dot{V}O_{2\max}$ difficult. Therefore, the subjects were asked to refrain from taking their medication before the exercise test in the laboratory. On the other hand, our subjects daily work under the influence of the drugs. Therefore, the short laboratory test obviously overestimated the $\dot{V}O_{2\max}$ of those under medication, at least of those taking some beta-blocking agent. The side-effects of the drugs among about 50 % of our subjects should be taken into consideration because most of the physically working subjects used beta-blocking drugs. It is obvious that their physical work capacity is decreased due to the medication during an 8-h workshift. However, the effects of medication should be studied under actual work conditions.

Individual changes in maximal oxygen consumption

The most important finding in this follow-up study was the marked decrease in $\dot{V}O_{2\max}$ at the individual level. For four men and five women the absolute $\dot{V}O_{2\max}$ decreased more than 20 % in four years after the age of 45 years. (See figures 1 and 3.) Such a decrease is manifold compared with that expected after the age of 30 years, namely, 0.75–1.0 % per year. The decrease in $\dot{V}O_{2\max}$ with age is due to the decrease in maximal heart rate, stroke volume, and arteriovenous oxygen difference, all of which decrease the efficiency of the oxygen transport system (20). Aging is associated with several changes in the circulatory system. Atherosclerosis decreases the blood flow to the organs, an accumulation of lipids in the coronary arteries disturbs the blood supply to the heart, an increase of collagen in the heart muscle decreases the contraction capacity of the heart, and systolic blood pressure increases due to a decrease in the elastic tissue of the aorta and to a weakening of the baroreceptor control mechanism (21).

In most cases a marked decrease in $\dot{V}O_{2\max}$ was associated with some medication for coronary heart disease, but also for two healthy women and one healthy man a 20 % decrease in four years was measured. Such a decrease in $\dot{V}O_{2\max}$ will increase the strain due to one's occupation, but it can also be the

first sign of developing or undetected disturbances in the cardiorespiratory system. A slightly, but systematically accelerated increase in blood pressure in an exercise test can be a predictor of developing hypertension (22). Of the occupational stress factors the following are associated with coronary heart disease: energetic peak loads, heavy dynamic and static muscular work, the use of muscular strength, poor work postures, and heat and cold as environmental exposures (23). Still today, physical work includes several stress factors which presuppose a healthy and stress-tolerant cardiorespiratory system. For decreasing the risks of physical work, employees should be examined regularly at one- to two-year intervals after the age of 40 years. The health examinations should include a submaximal exercise test for the cardiorespiratory system.

On the other hand, it was very positive to observe that $\dot{V}O_2\text{max}$ can be markedly increased independently of age. The absolute $\dot{V}O_2\text{max}$ increased more than 0.5 l for six men and one woman. The improvements were related to the base-line level so that those having a lower $\dot{V}O_2\text{max}$ had a greater improvement in $\dot{V}O_2\text{max}$. The improvement of $\dot{V}O_2\text{max}$ in this study material was probably due to the instructions given to the subjects after their first visit to the laboratory in 1981. The subjects were given their own results and also the reference values of their age group. Especially for those who had a lower fitness than average, a recommendation was given for physical training. In most cases walking was recommended. In the instructions, the intensity for walking was defined so that at the end of the session the person's breathing rate should be accelerated. A 20- to 30-min walk two to three times a week was recommended. The regularity of the exercise was emphasized. The interview in 1985 indicated that women mostly trained by walking, but men chose other activities like jogging, skiing, cycling, or swimming. It was, however, unclear why two-thirds of the men but only one-third of the women were motivated for physical training. It is possible that a systematic increase in physical activity habits is still today more difficult for aging women than for aging men due to home duties and the like.

Sufficiency of maximal oxygen consumption for physical work during aging

For aging workers in physically demanding occupations the most important question is whether their physical work capacity is good enough for the actual work demands. Although functional capacity decreases with age due to the weakening of several physiological functions, like vision, balance, temperature regulation, muscular strength, the most essential limitation obviously results from the weakening of the oxygen transport system (24). According to recommendations, physical demands during an 8-h workshift should not exceed 33—50 % of the $\dot{V}O_2\text{max}$, depending on the

rest periods included in the shift (25—27). If the work includes peak loads, manual work, harmful temperatures, crawling or climbing, 33 % of the $\dot{V}O_2\text{max}$ is recommended (1, 3). In different occupations other recommendations have also been discussed, like 40 % of the $\dot{V}O_2\text{max}$ for mail delivery (28). The results of the present study indicated that the older women in municipal occupations have, in most cases, such a low $\dot{V}O_2\text{max}$ that an aerobic demand of $1.0 \text{ l} \cdot \text{min}^{-1}$ during occupational work is too loading even though work-rest schedules are employed. A maximal aerobic capacity of $2.0 \text{ l} \cdot \text{min}^{-1}$ is needed as a minimum for a typical physical occupation, but, in our study, at the age of 55 years 63 % of the women had a $\dot{V}O_2\text{max}$ that was lower.

It should be mentioned also that the municipal jobs include peak loads, as well as outdoor work in cold winters and warm summers. Therefore the relative aerobic strain of our subjects varied from 9 to even 90 % of the $\dot{V}O_2\text{max}$ (5). It can be concluded that physically demanding jobs cannot generally be recommended for women after the age of 55 years. However, if older women are motivated for occupations in which the aerobic demands exceed 1.0 l of oxygen $\cdot \text{min}^{-1}$, their $\dot{V}O_2\text{max}$ should be at least $2.0 \text{ l} \cdot \text{min}^{-1}$. In addition, the work-rest regimens should be organized so that the rest pauses are frequent and long enough and so that rest is available immediately after the peak loads. Therefore, physical work for older women should be redesigned. In general, the physical demands of work should decrease with age and, on the other hand, possibilities for maintaining and even improving the $\dot{V}O_2\text{max}$ should be organized as a part of occupational activities.

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