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Joint effects of physical activity, body mass index, waist circumference and waist-to-hip ratio with the risk of cardiovascular disease among middle-aged Finnish men and women

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Aims To assess joint associations of physical activity and different indicators of obesity (body mass index, waist circumference, and waist-to-hip ratio) with the risk of cardiovascular disease (CVD).
Methods and results The study comprised 18,892 Finnish men and women aged 25–74 years without history of coronary heart disease, stroke, or heart failure at baseline. Physical activity, different indicators of obesity, education, smoking, blood pressure, total and high-density lipoprotein cholesterol and history of diabetes were measured at baseline. An incident CVD event was defined as the first stroke or coronary heart disease event or CVD death based on national hospital discharge and mortality register data. The median follow-up time was 9.8 years. Physical activity had a strong, independent, and inverse association with CVD risk in both genders. All obesity indicators had a significant direct association with CVD risk after adjustment for age, smoking, education and physical activity. Further adjustment for the obesity-related risk factors weakened the associations and they remained statistically significant in men only. Physical activity and the obesity indicators both predicted CVD risk in men, but in women the joint effect was inconsistent.
Conclusion Both regular physical activity and normal weight can reduce the risk of CVD. Physical inactivity seems to have an independent effect on CVD risk, whereas obesity increases the risk partly through the modification of other risk factors.

Introduction

Sedentary lifestyle and obesity are important lifestyle-related public health problems in the world.[1–3] Physical

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inactivity and excess body mass are not only associated with a number of health-related risk factors, but they also seem to be independent risk factors for cardiovascular disease (CVD), type 2 diabetes, and several types of cancers.[1–12] The prevalence of inactivity and obesity, and their negative health consequences are rapidly increasing in both developed and developing countries.[1,2,13]

Some prospective studies examining the relation between body weight and CVD mortality have reported varying findings, including a J-shaped,[14,15] direct association,[9,16–18] or no association.[19] Body mass index (BMI) is commonly used to estimate the association of body fattiness and CVD risk in clinical practice and epidemiological studies, but the principal limitation of BMI is that it does not distinguish fat mass from lean body mass.[2] Abdominal obesity measured by waist circumference or waist-to-hip ratio (WHR) is an important potential risk factor for chronic diseases.[2,3,20–23]

Two recent reviews have evaluated the relation between physical activity and CVD/cancer incidence and mortality.[6,7] They conclude that individuals who report regular physical activity are less likely than sedentary individuals to die from coronary heart disease, stroke, CVD, certain cancers and all causes. Several studies have assessed the independent and combined effects of fattiness and physical fitness on mortality.[17,19,24] Moderate or high level of cardiorespiratory fitness may be protective against the excess mortality among overweight and obese individuals. However, very few studies have assessed the joint associations of physical activity and different indicators of obesity with CVD risk, especially among women.[5,8]

The aim of this study was to examine both single and joint associations of physical activity, and three indicators of obesity (BMI, waist circumference, and WHR), with the risk of CVD in a large population-based cohort of middle aged and elderly men and women, and further to what extent the risk is modified by other behavioural and biological CVD risk factors.

Methods

Subjects

Three independent cross-sectional population surveys were carried out in Kuopio and North Karelia provinces in eastern Finland and in the Turku-Loimaa region in southwestern Finland in 1987, 1992, and 1997.[25] The survey was expanded to the Helsinki capital area in 1992 and northern province of Oulu in 1997. All surveys were conducted using the same methodology according to the WHO MONICA survey protocol.[26] The subjects included were 25–64 years of age, and in 1997 the age group of 65–74 years was also included. An independent population-based random sample, stratified by area, gender and 10-year age group, was taken every survey year according to the WHO MONICA protocol.[26] Subjects who participated in more than one survey were included only in their first survey cohort. The total sample size of the three surveys was 20,547. The participation rate varied by year from 74% to 88%.[25] The final sample comprised 8928 men and 9964 women after excluding subjects previously diagnosed with coronary heart disease (CHD) ($n = 672$), stroke ($n = 390$) and heart failure ($n = 408$) at baseline, and subjects with incomplete data on any required factors ($n = 185$). These surveys were conducted according to the ethical rules of the National Public Health Institute and the investigations were carried out in accordance with the Declaration of Helsinki.

Baseline measurements

A self-administered questionnaire was mailed to the participants in advance. It included questions about smoking, socioeconomic factors, physical activity, and medical history. Education level, measured as the total number of school years, was divided into birth cohort specific tertiles. The participants were classified as never, past, and current smokers.

Physical activity included occupational and leisure-time physical activity. A detailed description of the questions has been presented elsewhere,[10–12,27,28] and these questions were similar to those used and validated in the 'Seven Countries Study'.[29] The subjects reported their occupational physical activity according to the following three categories: (i) *light* was physically very easy, sitting office work, e.g., secretary; (ii) *moderate* was work including standing and walking, e.g. store assistant; and (iii) *active* was work including walking and lifting, or heavy manual labour, e.g. industrial work, farm work. Self-reported leisure-time physical activity was classified into three categories: (i) *low* was defined as almost completely inactive, e.g. reading, watching TV, or doing some minor physical activity but not of moderate or high level; (ii) *moderate* was doing some physical activity more than four hours a week, e.g. walking, cycling, etc; and (iii) *high* was performing vigorous physical activity more than three hours a week, e.g. running, jogging, skiing, or regular exercise in competitive sports several times a week. Occupational and leisure-time physical activity were merged and regrouped into three categories: (i) *low* was defined as subjects who reported light levels of both occupational and leisure-time physical activity; (ii) *moderate* was defined as subjects who reported moderate or high level of either occupational or leisure-time physical activity; and (iii) *high* was defined as subjects who reported a moderate or high level of both occupational and leisure-time physical activity.

At the study site, specially trained research nurses measured the height, weight, waist and hip circumferences, as well as blood pressure using a standardised protocol.[26] Height and weight were measured without shoes and with light clothing. BMI was calculated as weight in kilograms divided by the square of the height in metres. Waist circumference was measured midway between the lower rib margin and iliac crest. Hip circumference was measured at the level of widest circumference over the greater trochanters. WHR was calculated as waist circumference divided by hip circumference. The subjects were classified in four BMI categories: <20 (lean), 20–24.9 (reference group), 25–29.9 (overweight) and $\geqslant 30\ kg/m^2$ (obese). Sex-specific quartiles of waist circumference and WHR were used in the analyses.

Blood pressure was measured from the right arm of the participant who was seated for five minutes before the measurement. After blood pressure measurement, a venous blood specimen was taken. Total and high-density lipoprotein (HDL) cholesterol levels were determined from fresh serum samples by using an enzymatic method (CHOD-PAP, Boehringer MANNHEIM, Mannheim, Germany). All samples were analysed in the same laboratory.

Follow-up

Follow-up information was based on the Finnish hospital discharge register for non-fatal outcomes (hospitalised myocardial infarction and stroke) and the mortality register by the Statistics Finland for fatal outcomes (cardiovascular death). These registers were linked to the risk factor surveys using social security numbers assigned to every citizen of Finland. Combined non-fatal (myocardial infarction and stroke) and fatal (CVD) cases were defined as CVD incidence in the analysis. Follow-up data were available through 31 December 2001. Eighth, Ninth and Tenth Revisions of the International Classification of Diseases (ICD) were used to identify non-fatal myocardial infarction (410–411 and I21–I22, I24) and stroke (430–438 and I60–I66) cases, and fatal CVD (390–459 and I00–I99) cases.

Statistical analyses

SPSS for Windows 11.5 was used for statistical analysis. Differences in risk factors at different levels of physical activity were tested using analysis of variance or logistic regression after adjustment for age and study year. The Cox proportional hazards model was used to estimate the single or joint effect of different levels of physical activity, BMI, waist circumference, and WHR on the risk of CVD. The proportional hazards assumption in the Cox model was assessed with graphical methods, and with models including time-by-covariate interactions.[30] In general, all proportionality assumptions were appropriate. Dummy variables for BMI (<30 versus $\geqslant$30 kg/m^2), waist circumference, and WHR (quartiles of 1–3 versus the highest quartile), inactivity (low level of physical activity) versus activity (moderate or high level of physical activity) were used in the analyses of joint association. The analyses were first carried out adjusting for age and study year, and then further for systolic blood pressure, total and HDL cholesterol, education, smoking, and diabetes at baseline. To avoid the potential bias of our results from early mortality in the low activity group, additional analyses were carried out excluding the subjects who died during the first two years of follow-up. Chi-squared log-likelihood ratio test was used to compare relative abilities of the different physical activity and obesity measures on the CVD risk. A *p*-value less than 0.05 was considered as statistically significant. Exact *p*-values and confidence intervals are given in tables.

Results

During a median follow-up of 9.8 years (4.9 and 14.8 years for the 25th and the 75th quartiles, respectively), 523 men and 295 women had an incident CVD event, of whom 400 were coded as CHD, 372 as stroke, and 46 as other CVD deaths. General characteristics of the study population at baseline are given in Table 1. In general, physically active men and women were younger, had significantly lower BMI, waist and hip circumference, WHR, diastolic blood pressure, lower prevalence of smoking and obesity, and higher HDL cholesterol.

The age- and study year-adjusted hazard ratios of CVD associated with light, moderate, and high physical activity were 1.0, 0.57, and 0.52 (p < 0.001 for trend) in men, and 1.0, 0.62, and 0.51 (p < 0.001 for trend) in women, respectively (Table 2). After a further adjustment for education, smoking, systolic blood pressure, total and HDL cholesterol, diabetes and BMI, the hazard ratios were 1.0, 0.72, and 0.68 (p = 0.007 for trend) in men, and 1.0, 0.73, and 0.64 (p = 0.02 for trend) in women, respectively. These inverse associations did not appreciably change (data not shown) after additionally excluding the subjects who died during the first two years of follow-up. The combined measure of occupational and leisure-time physical activity was a better predictor for CVD than either occupational activity or leisure-time physical activity alone (data not shown).

BMI had a significant direct association with the CVD risk among both men and women after adjustment for age and study year, even though a slightly increased risk was found among the leanest subjects (Table 3). Compared with normal weight subjects (reference group: BMI 20–24.9), the hazard ratios of CVD among lean, overweight, and obese subjects were 1.10, 1.36, and 2.08 (p < 0.001 for trend) in men, and 1.24, 1.23, and 2.04 (p < 0.001) in women, respectively. Adjustment for education, smoking, and physical activity strengthened the associations slightly. After further adjustment for systolic blood pressure, HDL and total cholesterol, and diabetes, the association was still significant among men (p = 0.006 for trend) but became marginally significant among women (p = 0.06 for trend). When BMI was exam-

Table 1 Baseline characteristics according to physical activity levels among the Finnish population by sex

	Physical activity (men)			*p*-Value	Physical activity (women)			*p*-Value
	Low	Moderate	High		Low	Moderate	High	
Numbers of participants	999	4245	3684		1397	4763	3804	
Age (year)	47.9	48.0	42.9	<0.001	46.7	46.4	43.3	<0.001
Body mass index	27.3	26.6	26.6	<0.001	27.0	25.9	25.7	<0.001
Hip circumference (cm)	103	102	101	<0.001	103	101	101	<0.001
Waist circumference (cm)	96	93	93	<0.001	83	80	79	<0.001
Waist-to-hip ratio	0.93	0.92	0.91	<0.001	0.80	0.79	0.79	<0.001
Diastolic blood pressure (mm Hg)	86	85	85	0.03	81	80	80	0.06
Systolic blood pressure (mm Hg)	139	140	139	0.1	134	134	133	0.4
Total cholesterol (mmol/l)	5.8	5.7	5.7	0.002	5.6	5.6	5.6	0.4
High density lipoprotein cholesterol (mmol/l)	1.2	1.3	1.3	<0.001	1.5	1.6	1.6	<0.001
Education (year)	11.3	11.3	10.3	<0.001	11.3	11.3	11.2	0.04
Current smoking (%)	44.6	33.5	34.3	<0.001	25.4	20.3	19.6	<0.001
Obesity (%)[a]	26.7	17.9	14.1	<0.001	28.5	18.8	13.8	<0.001
The highest quartile of waist circumference (%)	37.8	26.4	18.3	<0.001	37.3	26.0	19.8	<0.001
The highest quartile of waist-to-hip ratio (%)	37.1	26.5	19.1	<0.001	33.7	25.7	20.9	<0.001

Adjusted for age and study years; values represent mean or percentage.
[a] Obesity was defined as body mass index $\geqslant$30.

Table 2 Hazard ratios for risk of cardiovascular disease according to different levels of physical activity by sex[a]

Physical activity	Numbers of events		Person—years		Hazard ratios (95% CI)					
					Men			Women		
	Men	Women	Men	Women	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Low	105	77	8235	12,686	1.00	1.00	1.00	1.00		1.00
Moderate	268	145	35,695	43,017	0.57 (0.46—0.72)	0.69 (0.55—0.87)	0.72 (0.57—0.91)	0.62 (0.47—0.81)	0.69 (0.52—0.91)	0.73 (0.55—0.97)
High	150	73	34,618	36,111	0.52 (0.40—0.67)	0.64 (0.50—0.84)	0.68 (0.52—0.88)	0.51 (0.37—0.71)	0.60 (0.43—0.83)	0.64 (0.45—0.89)
p for trend					<0.001	0.002	0.007	<0.001	0.006	0.02

[a] Model 1, adjusted for age and study year; model 2, adjusted for age, study year, education, smoking, and body mass index (in the continuous form); model 3, adjusted for age, study year, education, smoking, systolic blood pressure, total and HDL cholesterol, diabetes at baseline, and body mass index (in the continuous form).

Table 3 Hazard ratios for risk of cardiovascular disease according to different levels of body mass index, waist circumference, and waist-to-hip ratio by sex[a]

	Numbers of events		Person—years		Hazard ratios (95% CI)					
					Men			Women		
	Men	Women	Men	Women	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Body mass index										
<20	4	6	1336	5569	1.10 (0.40—2.98)	0.88 (0.32—2.40)	1.18 (0.43—1.61)	1.24 (0.54—2.87)	1.11 (0.48—2.56)	1.20 (0.52—2.79)
20—24.9	98	68	27,429	40,526	1.00	1.00	1.00	1.00	1.00	1.00
25—29.9	262	104	36,812	29,369	1.36 (1.08—1.72)	1.48 (1.17—1.87)	1.27 (1.00—1.61)	1.23 (0.90—1.68)	1.26 (0.92—1.72)	1.09 (0.79—1.50)
⩾30	159	117	12,972	16,350	2.08 (1.61—2.67)	2.12 (1.64—2.74)	1.60 (1.23—2.09)	2.04 (1.50—2.78)	1.99 (1.45—2.73)	1.49 (1.07—2.08)
p for trend					<0.001	<0.001	0.006	<0.001	<0.001	0.06
Waist circumference										
Quartile 1	66	25	21,252	22,913	1.00	1.00	1.00	1.00	1.00	1.00
Quartile 2	101	62	19,982	24,786	1.15 (0.84—1.57)	1.18 (0.86—1.60)	1.02 (0.75—1.40)	1.41 (0.88—2.25)	1.44 (0.90—2.31)	1.40 (0.87—2.23)
Quartile 3	143	72	19,595	22,107	1.37 (1.02—1.84)	1.43 (1.06—1.92)	1.18 (0.87—1.59)	1.37 (0.86—2.19)	1.41 (0.88—2.24)	1.17 (0.73—1.88)
Quartile 4	213	136	17,719	22,009	1.97 (1.49—2.62)	1.99 (1.50—2.64)	1.48 (1.10—1.98)	2.18 (1.40—3.39)	2.10 (1.35—3.28)	1.50 (0.95—2.39)
p for trend					<0.001	<0.001	0.008	<0.001	0.001	0.2
Waist-to-hip ratio										
Quartile 1	53	43	21,059	25,232	1.00	1.00	1.00	1.00	1.00	1.00
Quartile 2	92	57	21,029	24,031	1.19 (0.85—1.68)	1.17 (0.83—1.64)	1.02 (0.72—1.43)	1.09 (0.73—1.63)	1.07 (0.72—1.59)	1.02 (0.68—1.52)
Quartile 3	159	80	19,762	21,214	1.78 (1.30—2.44)	1.72 (1.26—2.36)	1.43 (1.03—1.96)	1.27 (0.87—1.86)	1.21 (0.83—1.77)	1.00 (0.68—1.47)
Quartile 4	219	115	16,699	21,337	2.62 (1.92—3.57)	2.46 (1.80—3.36)	1.83 (1.33—2.52)	1.60 (1.11—2.29)	1.44 (1.00—2.08)	1.01 (0.68—1.48)
p for trend					<0.001	<0.001	<0.001	0.03	0.1	1.0

[a] Model 1, adjusted for age and study year; model 2, adjusted for age, study year, education, smoking, and physical activity; model 3, adjusted for age, study year, education, smoking, systolic blood pressure, total and HDL cholesterol, diabetes at baseline, and physical activity.

ined as a continuous variable, the age- and study year-adjusted hazard ratios of CVD were 1.07 (95% CI 1.05—1.09) in men and 1.06 (95% CI 1.03—1.08) in women for each one-unit increase. Adjustment for education, smoking, and physical activity did not change the hazard ratios markedly. After further adjustment for systolic blood pressure, HDL and total cholesterol, and diabetes, these associations remained significant ($p = 0.007$ in men and $p = 0.016$ in women).

The age- and study year-adjusted hazard ratios of CVD across quartiles of waist circumference were 1.0, 1.15, 1.37, and 1.97 ($p < 0.001$ for trend) in men, and 1.0, 1.41, 1.37, and 2.18 ($p < 0.001$ for trend) in women, respectively (Table 3). Similarly, the age- and study year-adjusted hazard ratios of CVD across quartiles of WHR were 1.0, 1.19, 1.78, and 2.62 ($p < 0.001$ for trend) in men, and 1.0, 1.09, 1.27, and 1.60 ($p = 0.03$ for trend) in women, respectively. Adjustment for education, smoking, and physical activity did not change the hazard ratios markedly. After further adjustment for systolic blood pressure, HDL and total cholesterol, and diabetes, these direct associations were still significant among men but not among women. In both genders, and in women particularly, the effect of obesity on CVD risk was partly mediated through systolic blood pressure, HDL and total cholesterol, and diabetes. Exclusion of the subjects who died during the first two years of follow-up did not affect the associations between the obesity indicators and the risk of CVD markedly. When different measures of obesity were compared, WHR in men and BMI in women were slightly better predictors of CVD than others (data not shown). The age- and study year-adjusted hazard ratios of CVD in men were 1.025 (95% CI 1.02–1.03) for each 1-cm increase in waist circumference (as a continuous variable), and 1.60 (95% CI 1.44–1.79) for each 0.1-unit increase in WHR (as a continuous variable). In women, the corresponding hazard ratios were 1.02 (95% CI 1.01–1.03) and 1.36 (95% CI 1.14–1.61), respectively. Adjustment for education, smoking, and physical activity did not change the hazard ratios markedly but after further adjustment for systolic blood pressure, HDL and total cholesterol, and diabetes, these associations became non-significant.

Fig. 1 shows the joint association of physical activity, BMI, waist circumference, and WHR with CVD risk. In these analyses, the subjects were classified into four categories: both active and non-obese (the reference group), active but obese, inactive but non-obese, both inactive and obese. Obesity was defined either as BMI $\geqslant$ 30 or the highest quartile of waist circumference or WHR. Among men, physical inactivity or obesity alone increased the risk of CVD by 20–40%, and the combination of physical inactivity and obesity doubled the risk in comparison with the reference group. Among women, BMI $\geqslant$ 30 or physical inactivity alone increased the risk of CVD by 56% and 70%, respectively, and those women who had both high BMI and were inactive had a double risk compared to the reference group. The joint associations of physical inactivity and waist circumference, and particularly WHR, were inconsistent.

Discussion

The results of the present large population-based prospective study demonstrate that both physical activity and general and abdominal obesity predict the risk of CVD among middle-aged men and women. Physical activity has a strong protective effect on CVD risk and this association attenuated only slightly after the adjustment for other CVD risk factors. Whereas obesity increases the risk mainly through other risk factors, particularly among women. Exclusion of the subjects who died during the first two years of follow-up did not affect the results markedly.

Most studies,[4,9,14–18] but not all,[19] have indicated that overall obesity assessed by BMI is associated with increased risk of CHD or CVD incidence, and CHD or CVD mortality. Abdominal obesity, assessed by WHR or waist circumference, has been found to be a better predictor of total, CHD, and CVD mortality than BMI in some population groups,[20,21] but the prospective data of the effects of abdominal obesity on the CVD incidence are still scant. Some studies indicated higher death rates in the subjects with abdominal obesity who had an underweight (a low BMI and high WHR) than in those without abdominal obesity who were overall obese (a high BMI and low WHR).[20,21] Several studies found that both overall obesity and abdominal obesity were associated with the risk of CHD in both men and women.[22,23] In the present study, we found that BMI rather than waist circumference or WHR predicted CVD risk, especially in women.

A recent review on guidelines for healthy weight by Willett et al.[2] pointed out three potential methodological problems that can distort the association between obesity and health outcomes. The most serious problem is called reverse causation, another major concern is the failure to control for smoking, and the third problem is the inappropriate control for other risk factors. In the present study, we excluded the subjects with a history of CHD, stroke, and heart failure at baseline. We analysed the data also after exclusion of the early events, which did not change the results. In the analyses, smoking status was considered as a confounding factor in the intermediate model, and the physiological effects of excess fattiness (blood pressure, diabetes, and total and HDL cholesterol) were considered as mediating factors and included in the final model.

Our results are consistent with the findings of a number of prospective studies about the strong inverse association of physical activity, physical fitness with incidence of CHD, stroke, and CVD.[5–8] In general, these studies have reached a similar conclusion that the protective effect of physical activity is found in different population groups and is usually stronger in women than in men.[6] Walking also reduced the incidence of CHD among men and women.[5,8] However, occupational physical activity has been largely ignored in these surveys. This may cause greater errors in estimates of overall physical activity particularly in women and persons from lower socioeconomic groups.[3] National Institutes of Health Consensus Development Conference on Physical Activity and Cardiovascular Health concluded that intermittent or shorter bouts of activity (at least 10 min), including occupational, non-occupational, or tasks of daily living, also have similar cardiovascular and health benefits if performed at a level of moderate intensity (such as brisk walking, cycling, swimming, home repair, and yard work) with an accumulated duration of at least 30 min/day.[31] In our analyses, we included occupational physical activity as a component in the total physical activity.

A few prospective studies have evaluated the joint associations of physical activity, physical fitness, and body weight with CVD mortality, and the data are especially scarce among women. The Aerobic Center Longitudinal Study found that low cardiorespiratory fitness was a strong and independent predictor of CVD mortality among men, independent of body composition and other CVD risk factors.[17] Furthermore, they also indicated that

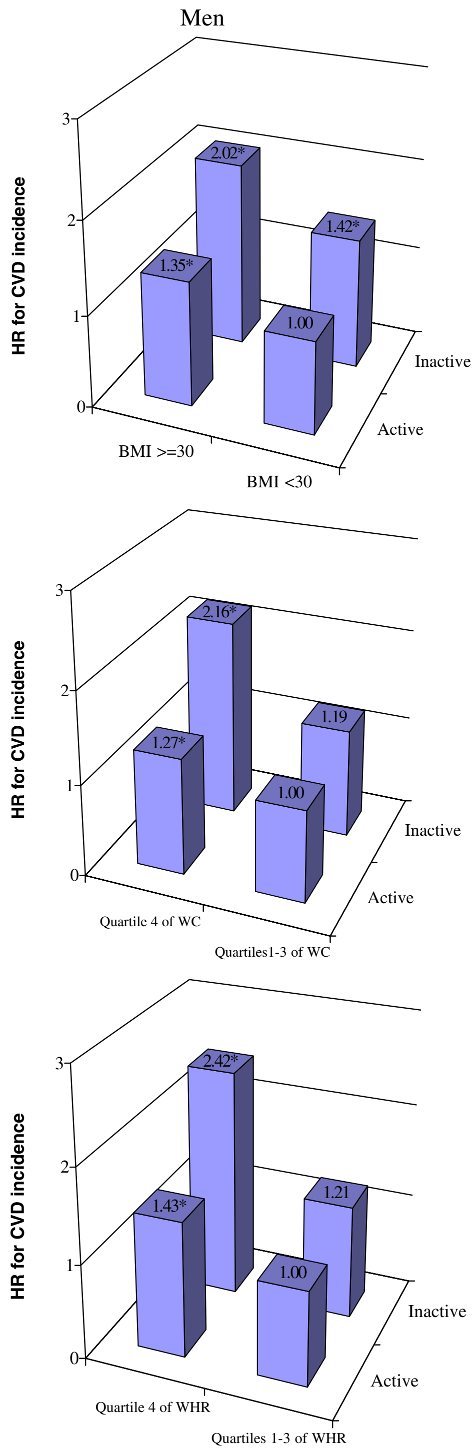

Fig. 1 Hazard ratios for CVD incidence according to levels of physical activity (low versus moderate or high), body mass index (<30 versus ⩾30), waist circumference and WHR (quartiles 1–3 versus quartile 4). Adjusted for age, study year, systolic blood pressure, total and high density lipoprotein cholesterol, education, smoking, and diabetes at baseline. *$p < 0.05$ vs. reference group.

overweight or obese men with moderate to high levels of cardiorespiratory fitness had a significantly lower risk of CVD mortality than normal-weight or overweight men with a low level of cardiorespiratory fitness.[17] The Lipid Research Clinics Study also assessed the effect of fitness and fattiness on longevity using data from 2506 men and 2860 women of mean age 46 years.[24] There was an increased risk of CVD mortality in men and women who were classified as fit-fat, unfit-unfat, and unfit-fat compared with people classified as fit-unfat. The result from the Nurses' Health Study and the Health Professionals' Follow-up Study found a strong, graded inverse association between physical activity and the risk of CHD, and this association was present in non-obese (BMI $\leqslant$29 kg/m^2) and obese (BMI > 29 kg/m^2) nurses, and in healthy weight (BMI < 25 kg/m^2), and overweight (25–29.9 kg/m^2) men.[5,8] The analysis from the first National Health and Nutrition Examination Survey assessed the CVD mortality rates among subjects with different levels of physical activity and BMI.[9] CVD mortality rates were the highest among those with both the least physical activity and obesity. On the other hand, the lowest CVD mortality rates were found among those with more exercise and normal weight.[9]

Our finding also supports the hypothesis that the adequate level of either occupational or leisure time physical activity, or both, can protect against the premature CVD in overweight and obese individuals. Weight reduction in obese people reduces the risk of death and CVD,[2] but it is well known that reducing weight is very difficult and, even at best, only a limited weight reduction may be achieved.[32] Therefore, it is also important to identify other ways to reduce the mortality and morbidity risks. It seems that increased physical activity is useful in this respect.

There are several strengths and limitations in our study. First, our study is population-based comprising a large number of both men and women from a homogeneous population. The median follow-up, 9.8 years, was sufficiently long during which a large number of CVD endpoint events were ascertained without losses of follow-up. Second, occupational physical activity was also included in the total physical activity. Third, we had data on standardised measurement of three different indicators of obesity, and a large number of other obesity-related risk factors, which may modify the association of obesity with the CVD risk. A limitation of our study was the self-report of physical activity. Using a questionnaire to assess habitual physical activity is crude and imprecise. Misclassification, particularly over-reporting of the amount of physical activity leads to an underestimation of effects of physical activity on CVD risk. It has been shown that measured physical fitness predicts mortality slightly better than self-reported physical activity.[33] Residual confounding may also have affected our results to some extent. Leisure-time physical activity has a direct, and physical activity at work has an inverse, association with socio-economic status. Even though the analyses were adjusted for education, unmeasured components of socio-economic status may strengthen the protective effect of leisure-time activity and weaken the protective effect of occupational activity. Moreover, several risk factors, such as triglycerides and apolipoprotein B, are not available for the present analysis. These factors, however, are most probably mediators (such as blood pressure, cholesterol, and diabetes) in the obesity and physical activity-related CVD risk, and therefore, including them in the analyses should not have influenced the interpretation of the role of obesity and sedentary lifestyle on CVD risk.

In conclusion, our study confirmed that both physical inactivity and obesity are important risk factors for CVD. Physical inactivity had a strong and consistent independent association with the CVD risk. The risk of CVD associated with obesity was partly mediated through other risk factors, such as blood pressure, blood lipid, and diabetes, in women particularly. All obesity indicators predicted the risk of CVD in men, but in women only BMI had an independent association after adjustment for the obesity-related risk factors.

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