Original Research Communications

Trends in waist-to-hip ratio and its determinants in adults in Finland from 1987 to 1997[1–3]

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ABSTRACT

Background: Although abdominal obesity has been shown to be an important risk factor for cardiovascular disease and a variety of other diseases, secular changes in fat distribution in populations have rarely been documented.

Objective: Our objective was to assess trends in waist-to-hip ratio (WHR) in the Finnish population during a 10-y period. In addition, we investigated the associations of WHR with body mass index (BMI), age, education, and lifestyle factors.

Design: Three independent cross-sectional surveys were carried out at 5-y intervals between 1987 and 1997. Altogether, 15 096 randomly selected men and women aged 25–64 y participated in these surveys.

Results: The WHR increased in both men and women during the 10-y period ($P < 0.0001$). In men, the strongest upward trend took place in the first 5-y period and then seemed to plateau; in women, the WHR continued to increase into the 1990s. In both sexes, the most prominent increase was observed in subjects aged ≥45 y. The WHR increased in all education-level groups, the lowest WHR being among those with the highest education. Age (18% in men, 12% in women) and BMI (33% in men, 25% in women) accounted for most of the variation in WHR, whereas only 3% was explained by education and lifestyle factors.

Conclusions: Abdominal obesity is a growing problem in Finland, especially in persons aged ≥45 y. These adverse changes in body shape continued to take place, particularly in women, in the 1990s. *Am J Clin Nutr* 2000;72:1436–44.

KEY WORDS Waist-to-hip ratio, abdominal obesity, waist circumference, body mass index, population studies, secular trends, lifestyle, men and women, Finland, FINRISK Study

INTRODUCTION

Height-weight indexes [mainly body mass index (BMI)] have been used widely in epidemiologic research aimed at exploring the association between obesity and various diseases (1, 2). Recently, however, an understanding of the importance of fat distribution, particularly abdominal obesity, as a risk factor for many diseases has become a matter of primary concern (3). Several studies showed that body composition is a better predictor of obesity-related metabolic complications than is body weight (4–6), although the independent contribution of visceral fat to the development of chronic diseases is still under review (7).

Abdominal obesity, measured as an elevated waist-to-hip ratio (WHR), was shown to be a strong risk factor for cardiovascular disease (4, 5, 8, 9) and for type 2 diabetes mellitus (10–12). The WHR was also found to be associated with an increased risk of breast cancer (13, 14).

More recently, it was suggested that it is not the fat distribution pattern but the absolute amount of intraabdominal fat that influences health risk (15). Moreover, waist circumference alone was suggested to be a better indicator of cardiovascular disease risk than is WHR (16) and was recommended as a tool for identifying a need for weight management (17). Hip measurement, however, was shown to provide additional information (eg, as an independent contributor to increased risk of type 2 diabetes) (18, 19). In all, there is a lack of consistency in the selection and use of anthropometric indicators for classification of abdominal fatness (3). Still, WHR continues to be a useful research tool in epidemiologic studies (20).

According to secular trends in BMI reported in Europe (21) and elsewhere (22–24), obesity is a growing worldwide health problem; it is also a growing problem in Finland (25). However, to our knowledge, little is known about changes in fat distribution and body shape in populations. Thus, the aim of this study was to investigate secular trends in abdominal obesity, determined by the WHR, in adults in Finland from 1987 to 1997. A further aim was to study how much of the variation in WHR could be explained by age, education, BMI, and lifestyle factors (smoking, alcohol consumption, and physical activity).

SUBJECTS AND METHODS

Participants

This study included data from 3 cross-sectional population surveys (the FINRISK study) carried out in 3 regions in 1987, 1992, and 1997. Two of the regions—the provinces of North Karelia and Kuopio—are situated in eastern Finland and one, including

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the cities of Turku and Loimaa and their nearby rural municipalities, is located in southwestern Finland. The surveys were expanded to the Helsinki capital area in 1992 and further to Oulu province, located in the northern part of Finland, in 1997. In this study, however, we used data only from the first 3 regions mentioned because they had been included in each survey since 1987.

For each survey, an independent random sample was drawn from the population register, covering the age range 25–64 y. The samples were stratified according to the World Health Organization Monitoring Trends and Determinants of Cardiovascular Disease (MONICA) protocol (26), ie, ≥250 subjects of each sex and in each 10-y age group were chosen from each region. The total sample comprised 9934 men and 9950 women, of whom 7385 men and 8132 women participated. After the exclusion of pregnant women (n = 145) and persons with missing data on waist or hip circumference (n = 276), the final sample comprised 7233 men and 7863 women. The participation rate varied yearly from 72.6% to 77.6% for men and from 75.3% to 80.9% for women. The protocol was approved by the Ethical Committee of the National Public Health Institute.

Measurements

The subjects were invited to a local health care center, where anthropometric measurements were made according to the study protocol by trained personnel. Weight and height as well as waist and hip circumferences were measured while the subjects wore light clothing and no shoes. Weight was measured to an accuracy of 100 g and height to an accuracy of 0.5 cm. BMI was calculated as weight (in kg) divided by height (in m^2). Waist circumference was measured midway between the lower rib margin and the iliac crest. Hip circumference was measured at the level of the widest circumference over the greater trochanters. Both waist and hip circumferences were rounded up to the nearest 0.5 cm. The WHR was calculated as waist circumference divided by hip circumference.

Along with the invitation to participate in the survey, a self-administered questionnaire was sent to the subjects to be completed at home. The questionnaire covered questions on socioeconomic factors, medical history, and lifestyle. We used education level, measured as the total number of school years, as the measure for socioeconomic status. On the basis of their years of education, the subjects were divided into tertiles within each birth year because the education level has changed during the past years in Finland, with younger people having a better opportunity to be educated than older people.

The subjects were classified into 4 groups according to their smoking habits: those who had never smoked (nonsmokers), those who had quit smoking ≥6 mo previously (exsmokers), those who had quit smoking <6 mo previously, and those currently smoking (smokers). We combined the latter 2 categories, defining both current smokers and those who had quit smoking <6 mo previously as smokers.

An alcohol consumption index was calculated by summing reported alcohol consumption during the previous year in terms of the type of alcohol consumed (beer, wine, or liquor), the frequency of consumption, and the amount consumed. The total index was then calculated as consumption of absolute alcohol in grams per week.

The measurements of physical activity had several components that were explained in more detail in the report of Fogelholm et al (27). Metabolic equivalents (METs), calculated as activity energy expenditure divided by resting energy expenditure (28), were used to estimate energy expenditure. Occupational strenuousness was divided into 4 categories, from physically very light office work to strenuous work, such as heavy industrial labor. To evaluate physical activity during travel to and from work, the subjects were asked whether they walked, rode a bicycle, or used motorized transportation as well as the daily duration of this activity. Furthermore, the daily MET index for leisure-time physical exercise was measured in terms of frequency and duration. The frequency was determined by asking how many times per week the subjects exercised during leisure time. The duration of these exercise sessions was grouped into 5 categories, ranging from 0 to ≥60 min/session.

Basal metabolic rate (BMR) was estimated from body weight by using equations from the World Health Organization, which were stratified by sex and age group (29). Resting energy expenditure was calculated by multiplying BMR by 1.1. Finally, these data were used to estimate energy expenditure at work, during travel to and from work, and during leisure-time physical activity. These calculations were used to determine the average daily amount of energy spent on these activities.

Statistical analyses

Data from the 3 regions were pooled together. Furthermore, data from the 3 surveys were analyzed together and the year of the survey was used as a factor in all analyses.

Trends in the mean anthropometric measurements were tested by analysis of variance by using the generalized linear model procedure of SAS (30); anthropometric measurement was used as the dependent variable. Region was adjusted for in these analyses because, although the differences in WHR between the regions were minor, the education level varied across the 3 regions. The analyses were also adjusted for age, except when trends were analyzed by education, because age had already been taken into account when the education variable was created. In addition, because the mean height of the subjects increased during the study years, all the analyses were done both with and without adjustment for height. Because the results did not change, height was not included in the final models. The adjusted mean WHR values were obtained by using least-squares means.

Tests for trends in mean WHR were carried out by using 2 models. In the first model, after adjustment for the above-mentioned variables, the year and the variable of interest (age, education level, or BMI group) were included in the model to examine the main effects of these factors. Then, in the second model, an interaction term—year by the variable of interest—was added to determine whether there were differences in trends between subgroups.

All the analyses were carried out separately for men and women, except tests of whether the phenomena were similar for both sexes. These tests were done by including sex, in addition to the variables described above, as an independent variable in the models and by adding an interaction term: sex by the variable of interest or by the interaction of interest.

Secular changes in lifestyle factors were also analyzed by means of analysis of variance, or by a chi-square test for smoking habits. Linear regression analysis was used to estimate the independent effect of single variables and the overall effect of age, education level, BMI, and lifestyle factors on the variation in WHR. Regression models were constructed by adding these explanatory variables one by one to the model, BMI being the last to be added.

Because the suggested cutoff points for WHR in the literature are based on arbitrary criteria, and no consensus about the appropriateness of the different cutoff points has been reached (3), we

TABLE 1
Anthropometric measurements of the participants in the 3 surveys

	1987 (n = 2964 men, 3193 women)	1992 (n = 2171 men, 2412 women)	1997 (n = 2098 men, 2258 women)	P for trend[1]
Men				
Weight (kg)	81.2 ± 12.5[2]	82.8 ± 13.0	84.0 ± 13.4	0.0001
Height (cm)	174.1 ± 0.07	175.6 ± 0.07	176.2 ± 0.07	0.0001
BMI (kg/m^2)	26.8 ± 3.8	26.8 ± 3.9	27.1 ± 4.1	0.019
Waist circumference (cm)	92.6 ± 10.7	94.5 ± 11.3	94.7 ± 11.6	0.0001
Hip circumference (cm)	101.9 ± 6.6	101.9 ± 6.7	102.2 ± 6.8	0.23
Waist-to-hip ratio	0.907 ± 0.06	0.926 ± 0.07	0.925 ± 0.07	0.0001
Women				
Weight (kg)	67.8 ± 12.5	68.4 ± 12.9	69.5 ± 13.5	0.0001
Height (cm)	160.8 ± 0.06	162.0 ± 0.06	162.8 ± 0.06	0.0001
BMI (kg/m^2)	26.3 ± 5.0	26.1 ± 5.0	26.2 ± 5.1	0.90
Waist circumference (cm)	79.8 ± 11.4	81.0 ± 11.9	81.5 ± 12.4	0.0001
Hip circumference (cm)	101.9 ± 9.2	102.0 ± 8.9	101.9 ± 9.3	0.97
Waist-to-hip ratio	0.781 ± 0.06	0.792 ± 0.07	0.797 ± 0.07	0.0001

[1] The mean values presented are crude means, but the ANOVA was carried out by adjusting for region and age with year as an independent factor.
[2] $\bar{x}$ ± SD.

determined the WHR corresponding to a BMI of 30 by using linear regression. According to the formula

$$\text{BMI} = -16.723 + 4.798 \times \text{sex} + 42.283 \times \text{WHR} \quad (1)$$

the cutoff points were 0.99 for men and 0.88 for women.

RESULTS

Over the 10-y period, the mean BMI increased significantly in men but did not vary significantly in women (**Table 1**). The mean hip circumference did not change significantly in either sex, whereas the mean waist circumference and WHR increased significantly in both men and women. The strongest upward trend in WHR took place between 1987 and 1992; the increase was significant in both sexes. In the latter period, from 1992 to 1997, the WHR continued to increase only in women.

The mean WHR increased with age (**Figure 1**). Furthermore, trends in the mean WHR varied across age groups, the strongest upward trend occurring in subjects of both sexes aged >45 y. The WHR increased from 0.919 to 0.945 in men aged 45–54 y and from 0.930 to 0.957 in those aged 55–64 y during the 10-y period. The increases in WHR in women of the same age were from 0.785 to 0.810 and from 0.808 to 0.827, respectively. In younger men and women, the changes in WHR varied from 0.003 to 0.014. The results remained unchanged after adjustment for BMI (data not shown).

The secular trends in WHR by age in men differed from those in women (interaction between sex, age, and year: $P < 0.0001$). The interaction between age and year was significant ($P < 0.0001$) in men only between 1987 and 1992, whereas in women no interaction was found in either of the 5-y periods. However, after adjustment for BMI, this interaction in women strength-

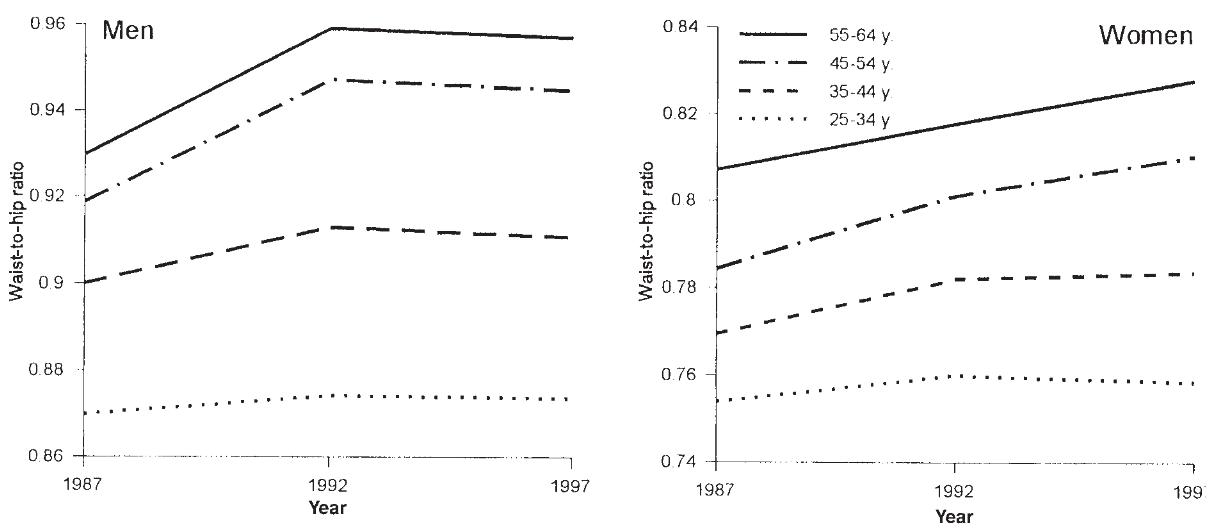

FIGURE 1. Waist-to-hip ratios by age in men (n = 7233) and women (n = 7833) from 1987 to 1997. Significant region-adjusted main effects for age and year and interactions for age × year, $P < 0.0001$ (ANOVA).

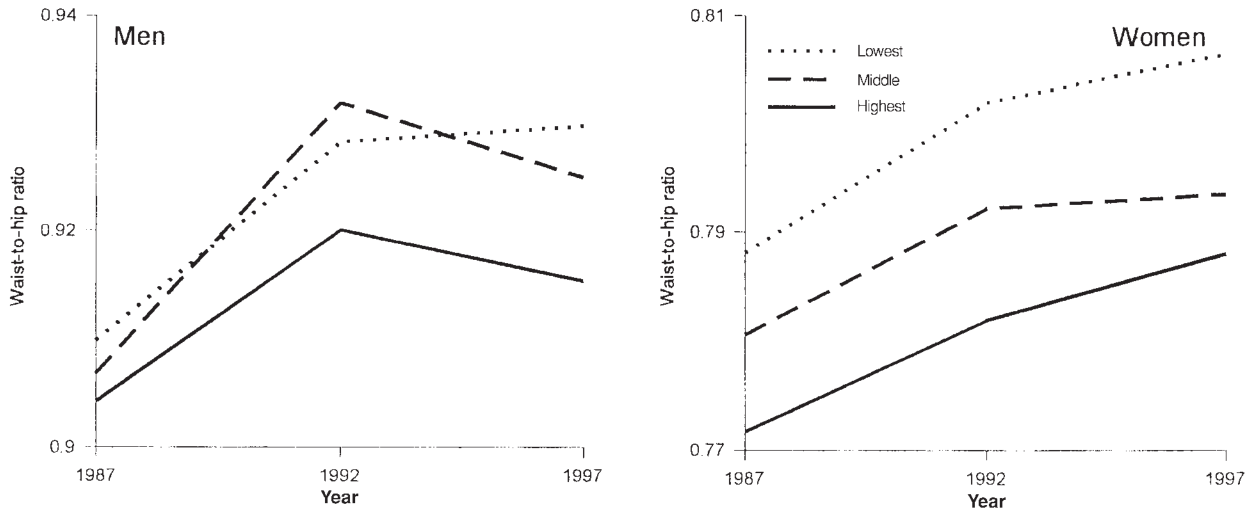

FIGURE 2. Waist-to-hip ratios by education level in men (n = 7093) and women (n = 7655) from 1987 to 1997. Significant main effects for education (P < 0.0001 for men and women) and year (P < 0.0001 for men and women) and interactions for education × year (P = 0.0596 for men) (ANOVA).

ened; the P value changed to 0.066 in the first 5-y period and was significant (P = 0.0014) in the latter 5-y period. Thus, the differences in WHR between older and younger men increased from 1987 to 1992 and then plateaued, whereas in women these differences continued to grow in the 1990s.

The upward trend in WHR was reflected in all education levels in both sexes from 1987 to 1997, the lowest WHR being among those with the highest education level (**Figure 2**). However, the changes in WHR by education in men were not similar to those in women (interaction between sex, education, and year: P = 0.0003). Whereas the mean WHR continued to increase in the men with the lowest education level, it seemed to plateau in the other groups in the 1990s. In contrast, in women, the differences between education levels remained stable during the 10-y period. After adjustment for BMI, the results did not change in women, but in men, the interaction between education and year became significant (P = 0.0046).

The mean WHR was calculated separately for subjects at 3 BMI levels: normal weight (BMI <25), overweight (BMI of 25–30), and obesity (BMI ≥30) (**Table 2**). The mean WHR increased regardless of BMI in both men and women, but the increase was most prominent in obese subjects.

The proportion of subjects with WHRs greater than the cutoff point, determined on the basis of the linear regression formula, increased from 10.8% to 19.6% in men and from 6.1% to 9.7% in women during the first 5-y period. In 1997, the proportion of men exceeding the WHR cutoff of 0.99 was 18.2% and that of women exceeding the WHR cutoff of 0.88 was 11.4%.

Changes in lifestyle (smoking habits, alcohol consumption, and physical activity) over the 10-y period are shown in **Table 3**. Alcohol consumption and energy expenditure at leisure time increased in both men and women during this period, whereas the proportion of inactive subjects at leisure time decreased. Simultaneously, energy expenditure at work and when traveling to and from work decreased in both sexes, whereas the total energy expenditure increased only in women. The proportion of male nonsmokers to smokers was higher in 1997 than in 1987. In contrast, the proportion of nonsmokers decreased in women, whereas that of exsmokers and smokers increased.

Being a smoker or an exsmoker, having higher alcohol consumption, and having higher energy expenditure at work were associated with higher WHRs in both sexes when age and education level and other lifestyle factors were taken into account (**Table 4**). Furthermore, energy expenditure when traveling to and from work and leisure-time physical activity were inversely associated with WHR. The model with these variables explained 22.6% of the variation in WHR in men and 18.1% in women. Age was the predominant determinant, accounting for 18.2% of this variation in men and 12.3% in women. About 3% of the variation was explained by lifestyle factors.

The proportion of WHR explained by the model increased to 53.8% in men and 40.7% in women after adjustment for BMI. BMI accounted for 32.8% of the variation in WHR in men and for 24.6% of the variation in women (**Table 5**). Adjustment for BMI changed the results such that the association between WHR and physical activity at work disappeared in both sexes and that between WHR and energy expenditure when traveling to and from work disappeared in men.

DISCUSSION

Both waist circumference and WHR increased remarkably in both sexes over the 10-y period, whereas hip circumference remained unchanged. An upward trend was also found in BMI in men but not in women. Our results for women were similar to those observed in Swedish women (20). In this population, which consisted of 3 population samples of women aged 38 and 50 y recruited in 1968–1969, 1980–1981, and 1992–1993, BMIs remained stable but WHRs increased. In a 12-y period, from the early 1980s to the 1990s, the mean WHR increased significantly only in women aged 38 y. Similar to the finding in our study, changes in WHR were partly independent of changes in BMI.

We observed an increase in WHR of 0.019 in men and of 0.011 in women from 1987 to 1997. Because the magnitude of these changes in WHR is difficult to interpret, we calculated,

TABLE 2
Waist-to-hip ratios (WHRs) and BMIs in subjects with normal weight, overweight, and obesity in 1987, 1992, and 1997

	Men				Women			
	1987 (*n* = 2962)	1992 (*n* = 2171)	1997 (*n* = 2097)	Difference, 1997–1987	1987 (*n* = 3192)	1992 (*n* = 2412)	1997 (*n* = 2257)	Difference, 1997–1987
WHR by group								
BMI < 25	0.858 ± 0.05[1]	0.873 ± 0.06	0.867 ± 0.05	0.009	0.750 ± 0.05	0.756 ± 0.04	0.758 ± 0.05	0.008
BMI 25–29.9	0.916 ± 0.05	0.935 ± 0.06	0.933 ± 0.05	0.017	0.792 ± 0.05	0.803 ± 0.06	0.811 ± 0.05	0.019
BMI ≥ 30	0.976 ± 0.05	0.998 ± 0.06	0.998 ± 0.05	0.020	0.836 ± 0.06	0.860 ± 0.07	0.867 ± 0.07	0.031
BMI by group								
BMI < 25	23.0 ± 1.5	23.0 ± 1.5	23.0 ± 1.6	0.0	22.3 ± 1.8	22.3 ± 1.8	22.3 ± 1.8	0.0
BMI 25–29.9	27.3 ± 1.3	27.2 ± 1.4	27.2 ± 1.4	−0.1	27.3 ± 1.4	27.2 ± 1.4	27.2 ± 1.4	−0.1
BMI ≥ 30	32.8 ± 2.7	32.8 ± 3.0	33.3 ± 3.1	0.5	34.0 ± 3.7	34.0 ± 3.9	34.4 ± 4.0	0.4

[1] $\bar{x}$ ± SD. With WHR as the dependent factor, $P = 0.0001$ for age group, $P = 0.0001$ for BMI group, and $P = 0.0001$ for year for both men and women and $P = 0.0028$ for the interaction of BMI group and year for men and 0.0001 for women (adjusted for region).

using linear regression, how the changes correspond to changes in BMI and, in turn, weight. According to our calculations, a change of 0.024 in WHR corresponds to a one-unit change in BMI, reflecting a weight change of 3.1 and 2.6 kg in men and women, respectively, of average height. Thus, the changes in WHR observed in our study correspond to a change in BMI of 0.8 in men and 0.5 in women. We observed, however, an increase in BMI of only 0.3 in men and no change at all in women, which confirms that changes in body shape and body composition have taken place in the Finnish population. Furthermore, BMI accounted for only 33% of the variation in WHR variation in men and for 25% of the variation in women.

A dramatic increase in WHR was shown in Indian, Creole, and Chinese adults (aged 25–74 y) in Mauritius from 1987 to 1992 (31). The WHR increased with age until the age of 64 y, which is consistent with our results. Our findings are a continuation of results reported by Marti et al (32), who observed age to be the strongest determinant of WHR variation in Finnish men and women. An increase in WHR with age was reported in the late 1980s by Shimokata et al (33) and was confirmed in a recent report, which included the 19 populations of the World Health Organization MONICA project (34).

In Swedish women, the upward trend in WHR between the 1980s and 1990s was more prominent in 38-y-old women than in women aged 50 y (20), whereas the secular trends in the Mauritanian population did not vary across age groups (31). In our study, the strongest upward trend occurred in those aged ≥45 y. In an earlier study (25), we found that BMI also varied across age groups. As with the WHR, the strongest upward trend was observed in the oldest age group (55–64 y) in men, but the increase in BMI among men aged 45–54 y was smaller than that in the youngest men. In women, BMI trends were the reverse of those of WHR, showing the strongest upward trend in the youngest women (25–34 y), with a plateau in the oldest women (25). This phenomenon was illustrated clearly in our analyses of WHR because, when adjusted for BMI, the interaction between age groups and survey year strengthened.

Because these analyses were based on cross-sectional data, the increasing WHRs, especially in the older age groups, could have been due at least in part to a cohort effect. The increasing WHR with menopause has been suggested to be linked to the possible role of estrogen in the regulation of visceral fat mass in women (35). In some studies (36, 37), including a study with a database overlapping the one used in our study (38), the use of hormone

TABLE 3
Smoking habits, alcohol consumption, and physical activity at each survey

	Men				Women			
	1987 (*n* = 2964)	1992 (*n* = 2171)	1997 (*n* = 2098)	*P* for trend	1987 (*n* = 3193)	1992 (*n* = 2412)	1997 (*n* = 2258)	*P* for trend
Smoking status[1]								
Nonsmoker (%)	36.3	38.5	41.4	0.001	72.0	68.3	66.7	0.001
Exsmoker (%)	25.1	23.8	25.1	0.49	9.7	10.9	13.7	0.001
Smoker (%)	38.6	37.7	33.5	0.001	18.3	20.8	19.6	0.067
Alcohol consumption (g/wk)[2]	75.0 ± 152.9[3]	94.9 ± 156.5	114.4 ± 187.7	0.0001	15.1 ± 35.9	23.5 ± 47.0	37.4 ± 67.9	0.0001
Physical activity[2]								
Total EE (MJ/d)[4]	13.53 ± 2.27	13.30 ± 2.26	13.41 ± 2.20	0.31	10.17 ± 1.43	10.08 ± 1.47	10.28 ± 1.54	0.0039
EE at work (MJ/d)	5.00 ± 1.89	4.69 ± 1.79	4.68 ± 1.80	0.0001	3.53 ± 1.16	3.34 ± 1.12	3.41 ± 1.16	0.0003
EE when traveling to work (MJ/d)	0.21 ± 0.37	0.17 ± 0.32	0.17 ± 0.32	0.0001	0.25 ± 0.31	0.22 ± 0.31	0.22 ± 0.31	0.0001
EE at leisure time (MJ/d)	0.41 ± 0.54	0.53 ± 0.63	0.59 ± 0.68	0.0001	0.30 ± 0.38	0.41 ± 0.47	0.49 ± 0.55	0.0001
Proportion of subjects inactive at leisure time (%)[1]	28.3	22.1	21.6	0.001	31.3	24.9	22.5	0.001

[1] Changes tested by chi-square test.
[2] Changes tested by ANOVA.
[3] $\bar{x}$ ± SD.
[4] EE, energy expenditure.

TABLE 4
Regression coefficients (β) with SEMs for the relations between waist-to-hip ratio and age, education level, smoking status, alcohol consumption, and physical activity[1]

	Men (n = 6653)			Women (n = 7200)		
	β ± SEM	P	r^2	β ± SEM	P	r^2
Intercept	0.73936 ± 0.00713			0.64364 ± 0.00615		
Age	0.00272 ± 0.00007	0.0001	18.2	0.00220 ± 0.00006	0.0001	12.3
Education level	−0.00407 ± 0.00097	0.0001	0.7	−0.00830 ± 0.00087	0.0001	1.9
Alcohol consumption	0.00331 ± 0.00047	0.0001	1.0	0.00402 ± 0.00143	0.0051	0.4
Smoking status						
Smoker versus nonsmoker	0.01017 ± 0.00179	0.0001	0.1	0.01130 ± 0.00187	0.0001	0.3
Exsmoker versus nonsmoker	0.01570 ± 0.00199	0.0001	0.7	0.01306 ± 0.00222	0.0001	0.4
Physical activity						
EE at work	0.00357 ± 0.00045	0.0001	0.6	0.00792 ± 0.00063	0.0001	1.5
EE when traveling to work	−0.00603 ± 0.00229	0.0084	0.1	−0.01682 ± 0.00228	0.0001	0.7
EE at leisure time	−0.00751 ± 0.00125	0.0001	0.3	−0.00444 ± 0.00151	0.0033	0.03
Survey year	0.00844 ± 0.00094	0.0001	0.9	0.00735 ± 0.00088	0.0001	0.8
Total r^2			22.6			18.1

[1] β based on continuous variables were calculated for the following variations: 100 g alcohol/wk and 1 MJ of energy expenditure (EE) per day at work, when traveling to work, and at leisure time.

replacement therapy (HRT) was shown to be inversely associated with WHR, but in another study no association was reported (39). Because our data on the use of HRT extended back only to 1992, these associations could not be investigated. However, on the basis of Finnish drug sales figures (40) and health behavior surveys (41), we know that the use of HRT increased during the past 2 decades. Between 1989 and 1996, the proportion of current users of HRT among women aged 45–64 y increased from 22% to 27% (41). Thus, it can be speculated that the trends in WHR observed in older women would have been even more adverse without the concomitant upward trend in HRT use.

The increasing WHRs observed in older subjects was alarming, especially when taken in conjunction with the argument that threshold values of waist circumference and WHR corresponding to critical amounts of visceral adipose tissue have generally been found to decrease with age (42). The proportion of men in the oldest age group who had WHRs >0.99 was 18% in 1987 and >30% in the 1990s. For women in the same age group, the proportion of those with WHRs >0.88 more than doubled, from 10% to 21%, over a 10-y period. Furthermore, although the mean WHR increased regardless of the BMI category (normal weight, overweight, or obesity) to which the subject belonged, the most prominent increase in WHR was observed among obese subjects. The proportion exceeding the above-mentioned cutoff point increased from 39% to 57% in obese men and from 20% to 40% in obese women.

Differences in WHR between education levels were seen, especially in women, such that those with the highest education level had the lowest WHR. However, the social gradient did not widen in the 1990s in women, whereas in men the upward trend was observed among those with the lowest education level only. The education-year interaction was strengthened with height adjustment because men with the lowest education level were shorter and the height increase over time among them was smaller than in other education-level groups. Similar associations were found earlier in some (43–45), but not all (46, 47), studies. Furthermore, associations between higher WHR and lower levels of social support were reported in middle-aged women (48). One suggested interpretation of this is that subjects with low socioeconomic status manifest several signs of stress, which in turn cause endocrine abnormalities (19).

Lifestyle factors were associated with WHR in both men and women. However, these factors explained only a small portion of the WHR variation. Our findings strengthen those of Duncan et al (49), who found that smokers and former smokers have higher WHRs than do nonsmokers. This positive relation between smoking and WHR was shown in several other studies (43, 44, 50–53), including earlier results from the database used in this study in 1987 (54) and in 1992 (only women aged 45–64 y) (38).

Keeping in mind that classifications and determinations of lifestyle factors may vary across studies, together with any independent associations described, it is hardly surprising that there are conflicting results on the relation between alcohol consumption and WHR. Measurements of alcohol consumption are known to be unreliable (55). Our findings were consistent with the results of several other studies (38, 53, 56, 57) that showed that WHR increases with alcohol consumption. A positive correlation between WHR and consumption of liquor, excluding other alcoholic beverages, was also reported (46), whereas in some studies no relation was found (44, 50). Even more complicated is the relation concerning physical activity and WHR. Similar to the finding in our study, WHRs declined with increased physical activity (44, 45, 49, 53). Furthermore, no association was found between activity at work and WHR (45, 49). Despite our initial finding of a positive association between WHR and energy expenditure at work, this association disappeared when BMI was taken into account.

In Finland, these lifestyle factors have changed mostly in an unfavorable direction, particularly in women, among whom alcohol consumption and smoking have increased. Undoubtedly, these changes have had some influence on observed changes in WHRs. However, the cross-sectional design of this study did not allow for any causal conclusions, such as the effect of smoking cessation on changes in WHR.

The strengths of this study include the fact that repeated surveys were conducted at the same time of each year, inclusion of a large number of participants, and the fact that the measurements were taken by trained staff in a similar way throughout the survey years, although data on neither between-examiner nor within-examiner differences in measurements of waist and hip circumferences were available. Furthermore, the participation rate remained high during the survey years and the questions used

TABLE 5
Regression coefficients (β) with SEMs for the relations between waist-to-hip ratios and age, education level, BMI, smoking status, alcohol consumption, and physical activity[1]

	Men (n = 6651)			Women (n = 7200)		
	β ± SEM	P	r^2	β ± SEM	P	r^2
Intercept	0.53187 ± 0.00632			0.52993 ± 0.00567		
Age	0.00151 ± 0.00006	0.0001	18.2	0.00094 ± 0.00006	0.0001	12.3
Education level	−0.00294 ± 0.00075	0.0001	0.7	−0.00368 ± 0.00075	0.0001	1.8
BMI	0.01076 ± 0.00016	0.0001	32.8	0.00704 ± 0.00013	0.0001	24.6
Alcohol consumption	0.00215 ± 0.00036	0.0001	0.6	0.00471 ± 0.00122	0.0001	0.5
Smoking status						
Smoker versus nonsmoker	0.00928 ± 0.00138	0.0001	0.3	0.01173 ± 0.00159	0.0001	0.3
Exsmoker versus nonsmoker	0.00385 ± 0.00155	0.013	0.03	0.00851 ± 0.00189	0.0001	0.2
Physical activity						
EE at work	−0.00043 ± 0.00035	0.22	0.02	0.00096 ± 0.00055	0.083	0.003
EE when traveling to work	−0.00276 ± 0.00177	0.19	0.05	−0.00925 ± 0.00195	0.0001	0.2
EE at leisure time	−0.00867 ± 0.00096	0.0001	0.4	−0.00299 ± 0.00129	0.020	0.005
Survey year	0.00722 ± 0.00073	0.0001	0.7	0.00715 ± 0.00075	0.0001	0.7
Total r^2			53.8			40.7

[1] β based on continuous variables were calculated for the following variations: 100 g alcohol/wk and 1 MJ of energy expenditure (EE) per day at work, when traveling to work, and at leisure time.

remained the same. However, the questions on physical activity yielded only a crude estimate of activity, and the specific components of the daily leisure-time activities, except for sports, could not be determined (27). A further limitation was that these data were not representative of all of Finland because they included only 2 regions in the eastern part and 1 in the southwestern part. Furthermore, because the samples were stratified, the age distribution in our data was skewed toward older age groups compared with the age distribution of the general population in these 3 regions. Thus, when the whole age group (ages 25–64 y) was taken into account, the mean estimates of the WHR and BMI and the proportion of the subjects with values exceeding the WHR cutoff points may, to some extent, have been overestimated.

Whether waist circumference or WHR should be used in assessments of obesity-related risks is under strong debate. A recent report concluded that waist circumference may be the best overall predictor of abdominal obesity, whereas the use of WHRs as a surrogate measure of visceral adiposity was not recommended (58). Furthermore, waist circumference and WHRs are said to measure different aspects of the human body—waist circumference reflects mainly the degree of overweight (34). However, it should be kept in mind that both WHR and waist circumference are imperfect proxies for visceral adipose tissue accumulation (9). Still, with the help of these easily obtainable measurements, the changes in the risk of obesity-related diseases could be monitored.

Regardless of which index of central adiposity is used, there is growing concern about the marked increase in abdominal obesity in Finland. This adverse trend was observed primarily among subjects aged ≥45 y. These changes in body shape continued to occur in the 1990s, especially in women. Although a small portion of the variation in WHR was explained by lifestyle factors, most of the variation was accounted for by age and BMI.

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