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The Public Health Impact of Obesity

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■ **Abstract** The increase in obesity worldwide will have an important impact on the global incidence of cardiovascular disease, type 2 diabetes mellitus, cancer, osteoarthritis, work disability, and sleep apnea. Obesity has a more pronounced impact on morbidity than on mortality. Disability due to obesity-related cardiovascular diseases will increase particularly in industrialized countries, as patients survive cardiovascular diseases in these countries more often than in nonindustrialized countries. Disability due to obesity-related type 2 diabetes will increase particularly in industrializing countries, as insulin supply is usually insufficient in these countries. As a result, in these countries, an increase in disabling nephropathy, arteriosclerosis, neuropathy, and retinopathy is expected. Increases in the prevalence of obesity will potentially lead to an increase in the number of years that subjects suffer from obesity-related morbidity and disability. A 1% increase in the prevalence of obesity in such countries as India and China leads to 20 million additional cases of obesity. Prevention programs will stem the obesity epidemic more efficiently than weight-loss programs. However, only a few prevention programs have been developed or implemented, and the success rates reported to date have been low. Obesity prevention programs should be high on the scientific and political agenda in both industrialized and industrializing countries.

BACKGROUND

Awareness of the association of obesity with health problems is longstanding. A classical example of the emergence of an obesity-disease link was the 1921 observation by Joslin that a large proportion of diabetes patients were overweight (23, 37). Another classical observation was the notation, by Hinsworth, of a decrease in the prevalence of diabetes in countries with food shortages in World War I (23, 29). The Metropolitan Life Insurance Company's development of "desirable weight" tables with respect to greatest expected longevity is a major marker for concern about health effects of obesity (60).

During the past few decades, the prevalence of obesity has grown to epidemic proportions, and this condition is now known to be a major contributor to the global burden of disease (92). Currently, more than 50% of the US population is

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overweight and approximately 20% is extremely overweight, or obese (16). Obesity prevalence is still increasing rapidly, not only in industrialized countries but also in nonindustrialized countries, particularly in those undergoing economic transition (79). Worldwide, around 250 million people are obese, and the World Health Organization has estimated that in 2025, 300 million people will be obese (93). Attitudes toward obesity differ across populations and, with economic changes, may change within populations over time. In industrialized countries, obesity is most common among those with low socioeconomic status. The opposite is true in nonindustrialized countries, where obesity is most often seen among individuals with high income and may be considered a status symbol. This may change as nonindustrialized countries become more affluent and obesity is seen increasingly in those with low socioeconomic status (76).

The two most important risk factors for mortality in the industrialized countries are cardiovascular disease (CVD) and cancer. CVD is a major cause of mortality, but also a major cause of disability (71). Costs for survivors of heart disease are enormous because of blood pressure–lowering drugs, antithrombotics and diuretics. Stroke survivors often suffer from such disabilities as mood disorders and impaired neuro-musculoskeletal functions. In many areas of the United States and Europe there is quick access to a hospital at the time a heart attack or stroke occurs. Fatalities associated with such events are therefore lower and CVD-related disability consequently higher in industrialized than in non-industrialized countries. Thus, although disability due to obesity-related CVD will increase in both industrialized and industrializing countries, the increase will be largest in the industrialized countries.

Diabetes is by far the most expensive public health consequence of obesity (94). In industrialized countries, severe forms of type 2 diabetes are controlled relatively well by insulin therapy. However, the industrializing countries—in which a huge obesity-linked diabetes epidemic is expected—will not be able to afford sufficient insulin therapy. Under such circumstances, uncontrolled glucose levels would lead to millions of patients developing nephropathy, arteriosclerosis, neuropathy, retinopathy, and related disability. The increase in disability due to obesity-induced diabetes will, therefore, be larger in industrializing than industrialized countries.

The direct costs of obesity are now estimated to be around 7% of total health care costs in the United States (10) and around 1%–5% in Europe (72). Narbro calculated that approximately 10% of the total costs of loss of productivity due to sick leave and work disability might be attributable to obesity-related diseases (59). Because of the increasing prevalence and costly consequences, obesity is now being recognized not only as a risk factor in the clinical setting but also as an important threat to public health. The public health impact of obesity should be measured by its combined effect on disability and mortality (Figure 1). Obesity can act through its relationship with other morbidities and appears to have a direct effect on disability (26, 48) (Figure 1). The current focus is also on outcomes such as quality of life and physical, social, and mental

functioning. These obesity-related outcomes increase in importance as population longevity increases (20).

This review outlines obesity as a public health problem. We first discuss definitions and trends of obesity and describe the role of obesity as a risk factor for all-cause mortality and the development of cancer. We then describe the role of obesity as a risk factor for CVD and type 2 diabetes mellitus. In addition, we address current evidence on obesity as a risk factor for such musculoskeletal disorders as osteoarthritis, work disability, and respiratory disorders. Finally, we discuss the use of body weight measurements in the elderly, who represent an increasingly important population with regard to the impact of obesity on the public health.

DEFINITIONS

Obesity

The World Health Organization definitions of overweight and obesity are based not only on the risks of increased mortality, but also on increased morbidity-risks (92) (Table 1). A BMI below 18.5 kg/m^2 is defined as underweight; a BMI between 18.5 and 24.9 is normal weight. Overweight individuals, those with a BMI between 25 and 29.9 kg/m^2, are at increased risk of morbidity and should avoid further weight gain. Weight loss in overweight people is recommended when other risk factors for disease are present. Severely overweight or obese people, those with BMIs of 30 kg/m^2 or higher, are at highly increased risk of disease irrespective of the presence of other risk factors and weight loss is recommended for all. Cross-culturally, the implication of a certain BMI level with respect to body fatness and fat distribution might vary across populations. Asian populations, for instance, have a higher absolute risk for the onset of type 2 diabetes mellitus than do Caucasian populations with the same level of BMI (41). The International Diabetes Institute and the International Obesity Task Force of the World Health Organization argue that lower BMI cut points should be used for Asian populations than for Caucasian populations (33).

Body Fat Distribution

The ratio of waist circumference divided by the hip circumference (WHR) is a measure of fat distribution on the body. This ratio may be misinterpreted as specific for abdominal fat (the numerator of the ratio), although it is also influenced by the amount of fat in the gluteal region (the denominator). Abdominal fat can be estimated with greater precision by the waist circumference alone (75a). The waist circumference is measured midway between the lower rib margin and the iliac crest, with the person in a standing position. Although the waist circumference is statistically significantly associated with stature, the correlation is sufficiently low to ignore adjustment for body height in persons aged 20–60 years.

TABLE 1 Definitions of body mass index and waist circumference categories[a]

Determinant	**Body mass index (kg/m^2)**	
Underweight	<18.5	
Normal weight	18.5–24.9	
Moderately overweight	25.0–29.9	
Overweight	≥25.0	
Preobese	25–29.9	
Obesity	≥30.0	
Obese class I	30–34.9	
Obese class II	35–39.9	
Obese class III	≥40.0	
	Waist circumference	
	Women	Men
Above action level 1	≥80 cm (∼32 in)	≥94 cm (∼37 in)
Above action level 2	≥88 cm (∼35 in)	≥102 cm (∼40 in)

[a]Body mass index categories are defined according to the World Health Organization guidelines (92). Waist circumference categories are suggested by Lean et al (46).

Lean et al suggested that action levels based on waist circumference replace BMI and WHR as measures of obesity (46) (Table 1). These action levels seemed appropriate for identifying those with cardiovascular risk factors, type 2 diabetes mellitus, or shortness of breath when walking upstairs (27, 44). However, this issue is still under debate (57). For example, Molarius & Seidell (57) have noted that criteria underlying these waist circumference action levels were based on arbitrary levels of the WHR and that the evaluations with respect to risk were based on cross-sectional data.

Attributable Risk

In measuring the impact of obesity on mortality, morbidity, or disability it is useful to calculate the fraction of an outcome that is attributable to obesity (the attributable fraction), using the proportion of obesity and the relative risk:

$$AF_p = \frac{p(RR - 1)}{p(RR - 1) + 1},$$

where *AF* is the attributable fraction, *p* the proportion of men in the body mass index (BMI) category, and *RR* the corresponding relative risk. To evaluate the different impact of obesity on mortality and morbidity, one can easily compare relative risks, as the proportion of obesity will be equal for each attributable fraction

calculation. In this review, the relative risks of categories of BMI for all-cause mortality, coronary heart disease, stroke, and type 2 diabetes mellitus are illustrated using US data from the Health Professionals Follow-Up Study (2, 7, 69, 89) and the Nurses' Health Study (5, 52, 54, 68). Both studies describe age-adjusted relative risks for these outcomes.

PREVALENCE AND TRENDS

Currently, more than half the US population is overweight (BMI $\geq$25 kg/m^2) and around 20% is obese (BMI $\geq$30 kg/m^2) (16). The US National Health and Nutrition Examination Surveys showed a marked increase in obesity between the first survey cycle in 1960–61 and the third cycle in 1988–94 in the United States (16). More recent data on obesity prevalence and trends in the United States are from the Centers for Disease Control and Prevention telephone survey data. Among respondents aged 18 years and older, obesity prevalence increased by around 50 percent between 1991 and 1998, with higher prevalence rates occurring in eastern states (56) (Figure 2). The absolute prevalence rates reported by Mokdad et al (56) are probably underestimations because they are based on self-reported height and weight. Obese people tend to underreport their weight more than do people with acceptable weight (61).

Data from the Third National Health and Nutrition Examination Survey (NHANES III) are based on direct measurements of height and weight. These data indicate that for persons aged 20–74 years, the prevalence of overweight

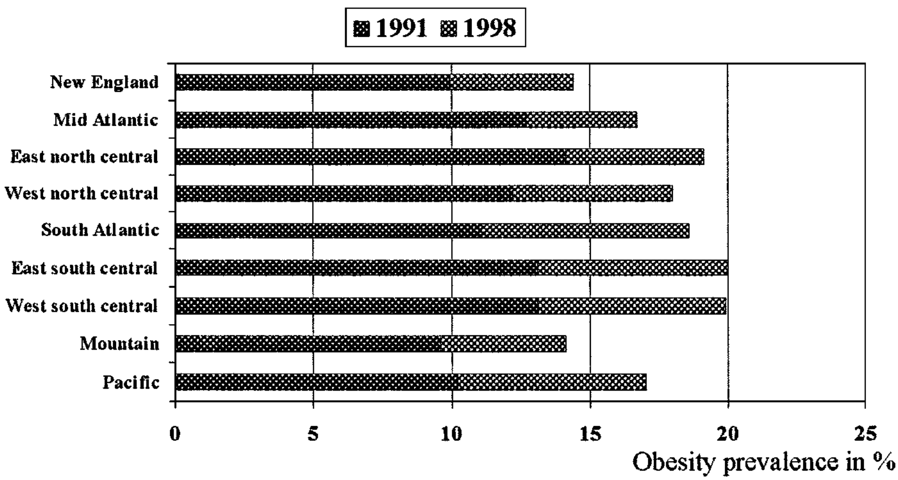

Figure 2 The increase in obesity in the United States. Data were derived from Mokdad et al (56) and are based on self-reported body weight and height.

(BMI $\geq$25 kg/m^2) was 59.3% in men and and 49.6% in women. In the same survey, 19.9% of the men and 24.9% of the women were obese (BMI $\geq$30 kg/m^2). In women, the prevalence of those who were overweight or obese was even higher in nonwhite populations. Among the non-Hispanic black and Mexican-American respondents in NHANES III, 20% of the men and approximately 35% of the women were obese (16).

Cross-National Differences

It is less common to be overweight (BMI 25–29.9) in most European countries than it is in the United States, but the prevalence of overweight adults in Germany, Finland, and Britain is substantial—more than 50%. Obesity (BMI 30 or above) also is generally less common in Europe than in the United States, around 10%–20% of adult men and 15%–25% of women (75). In Western European study centers participating in the World Health Organization (WHO) MONICA study, the prevalence of obesity ranged from 10% to 24% among men and from 9% to 25% among women aged 35–64 years in 1989–1996. Obesity was more common in Eastern Europe, especially among women. In Poland and Russian study centers, the prevalence of obesity was around 40% (58). The increase in obesity between the initial MONICA survey in 1979–1989 and the final survey in 1989–1996 was less marked for the European than in the single US study center in Stanford, California (58). The increase in the US study center was nearly as large as the 50% increase reported for the overall US population between 1991 and 1998 (56).

Obesity rates from countries in various levels of development were reported by Martorell et al (55) for women aged 15–49 years. In the poorest countries these authors noted a strong relationship between the gross national product and the prevalence of obesity. Prevalence was estimated at 0.1% in South Asia, 2.5% in sub-Saharan Africa, 9.6% in Latin America and the Caribbean, 15.4% in Kazakhstan, Turkey, and Uzbekistan, 17.2% in the Middle East and North Africa, and 20.7% in the United States (55).

Within-Country Differences

Data from NHANES and from the Centers for Disease Control and Prevention Behavioral Risk Factor Surveillance System (BRFSS) showed equivalent increases in obesity across different race/ethnic groups and educational categories in the United States (16, 56). Molarius et al (58) described most of the increase in obesity in the European MONICA study populations as being among those with the lowest socioeconomic status. Thus, the inequality in obesity prevalence widened between categories of socioeconomic status (58). In nonindustrialized countries, obesity often is a marker of relatively high socioeconomic status. Seidell & Rissanen (76) described the increase in obesity as most notable in those countries undergoing rapid economic transition and more notable in urban areas than in rural areas. Martorell et al (55) described obesity as mostly concentrated among urban and higher-educated women in very poor countries, such as in sub-Saharan Africa.

In more developed countries, such as Latin American countries and Kazakhstan, Turkey, and Uzbekistan, obesity rates were more equal across categories of urbanization and education (55). Popkin et al (65) reported a difference in the association between socioeconomic status and obesity in rural and urban areas in China in 1993. In urban areas, obesity was most common among those with low socioeconomic status, whereas in rural areas, obesity was most common in those with relatively high socioeconomic status (65).

OBESITY AND MORTALITY

Although obesity has been considered a risk factor for mortality for several decades, not all studies have confirmed the relationship between obesity and mortality. Sjöström's review indicated that the studies showing no positive association between BMI and mortality were generally those with short duration of follow-up or small sample size, or which did not take smoking into account (81). Manson et al (53) argued that adjustment for hypertension and unfavorable lipid levels could lead to underestimation of the effect of obesity on mortality. These authors pointed out that high BMI is related to the increased blood pressures and unfavorable lipid levels that predispose to increased mortality. When analyzing the impact of obesity on increased mortality, one should, therefore, not adjust for these intermediates of the BMI-mortality relationship in the statistical models. Manson et al also argued that the first 5 years of mortality should be eliminated from such analyses to account for possible weight loss, as a consequence of subclinical disease, among individuals who died early in the follow-up period (53). Furthermore, as smokers are known to be leaner and to have higher risks of obesity and the risk of death for obesity could be different among smoking categories, it is necessary to calculate the effect of obesity on mortality across different smoking categories (78).

Recent studies have reaffirmed high BMI levels as risk factors for all-cause mortality (53, 81). Mortality risk increased for BMI above 27 kg/m^2 in both the Nurses' Health Study (54) and the US Health Professionals Follow-Up Study (2). Characteristics of the US Health Professionals Follow-Up Study and the Nurses' Health Study are described in Tables 2 and 3. In these studies, the relative risks associated with high BMI are lower for all-cause mortality than for disease incidence, i.e., for type 2 diabetes mellitus, myocardial infarction, and ischemic stroke (Figures 3 and 4).

Stevens et al (82) showed that relative risks of mortality associated with high BMI were lower at older ages. This finding was based on analyses of BMI-mortality relation in approximately 62,000 men and 262,000 women who had never smoked and who were followed from 1960 through 1972. Calle et al (4) concluded that the relation between high BMI and increased mortality was more pronounced in white than in black people and was stronger among never-smokers than among smokers. Their analysis was based on follow up of more than 1 million US men and women aged 30 and over mean age of 57 years from 1982 through 1996.

TABLE 2 Relations between obesity and several forms of cancer[a]

Evidence	Cancer
Convincing	Endometrium
Probable	Breast (postmenopausal) Kidney
Possible	Gallbladder (particularly in women)
	Colon (less consistent for women)
Insufficient	Thyroid
Probably none	Pancreas Prostate

[a]Data adapted from the World Cancer Research Fund and the American Institute for Cancer Research (95).

OBESITY AND CANCER

The relationship between obesity and several types of cancer has been relatively neglected in most recent monographs on obesity. However, the comprehensive review of diet and cancer by the American Institute for Cancer Research and World Cancer Research Fund (WCRF), includes extensive coverage of this topic (95). The incidence of some cancers is related to body size or to BMI. According to the WCRF review, evidence relating BMI and cancer is strongest for endometrial

TABLE 3 Characteristics of the Nurses' Health Study on US women[a]

Outcome	Baseline	Follow-up	Subjects at baseline	Cases
All-cause mortality (54)	1976	1976–1984	115,195	4726
Coronary heart disease (52): non-fatal myocardial infarction	1976	1976–1992	155,886	306
Stroke (68): Ischemic stroke	1976	1976–1992	116,759	403
Type 2 diabetes mellitus (5): self-reported	1986	1986–1994	43,581	705

[a]See Figure 3.

TABLE 4 Characteristics of the Health Professionals Follow-up Study on US men[a]

Outcome	Baseline	Follow-up	Subjects at baseline	Cases
All-cause mortality (2)	1986	1986–1996	39,756	1972
Coronary heart disease (69)[b]	1986	1987–1996[c] (53 fatal)	29,122	420
Stroke (89)[d]	1986	1987–1992[c]	28,643	118
Type 2 diabetes mellitus (7): self-reported	1986	1986–1991	27,983	302

[a]See Figure 4.

[b]Fatal myocardial infarction, nonfatal myocardial infarction, coronary artery bypass graft, and percutaneous transluminal coronary angioplasty.

[c]Participants contributed follow-up time from 1987.

[d]Ischemic, hemorrhagic.

cancer (Table 4). A BMI exceeding 30 kg/m^2 is associated with a one and a half to three times higher risk of developing endometrial cancer than a BMI between 20 and 25 kg/m^2 (95). The WCRF review classified the relationship between high BMI and breast and kidney cancer as "probable," with an approximately 1.8-fold higher risk for those with a BMI exceeding 27 kg/m^2 compared with those having a BMI below 17 kg/m^2. There is evidence for a possible relationship between high BMI and colon cancer, less consistent for women than for men (95). Gallbladder cancer is also possibly associated with high BMI, particularly among women (95). The importance of obesity-induced gallstones, which are themselves a risk factor for gallbladder cancer, in the association of obesity and gallbladder cancer is uncertain (49, 50, 95). Based on a small number of case-control studies (95), little or no evidence was found for a relationship between obesity and cancer of the thyroid.

There is also a relationship between cancer and low BMI (95). This is probably confounded by smoking and cancer-induced weight loss. Smokers tend to be leaner than nonsmokers and are at increased risk of cancer.

Breast cancer risks are often considered separately for occurrence pre- and postmenopausally. In the Nurses' Health Study follow-up from 1986–1994, a significant relationship was found between large waist circumference and postmenopausal breast cancer incidence except among current and past postmenopausal hormone users (31). Obesity seems to be slightly protective for premenopausal breast cancer (86). Some studies have reported a positive relationship between obesity and premenopausal breast cancer. However, such findings might be explained by weight

gain shortly after diagnosis, especially among women who underwent chemotherapy (86). Tall women have a greater risk of breast cancer than short women, because of the larger number of potential cancer target cells (30).

The American Cancer Society's prospective follow-up study provides estimates of the association of obesity with cancer mortality among 750,000 men and women aged 30 years and older, who were followed from 1960 to 1972 (22). Obese men had a 1.33 higher and obese women a 1.55 higher mortality rate from cancer than did their normal-weight peers. In this study, overweight was defined with the relative weight index, calculated as the individual's body weight divided by the average weight of all respondents in that sex-age group and multiplied by 100. Obesity was defined as a relative weight index of 140 or more, normal weight was defined an index of 90–109 or within 10% of the group average. Among men, the relative risk of obesity was highest for mortality due to cancer in the colon and the prostate. Among women, the relative risk was highest for cancer in the endometrium (risk was about five times higher in obese women than in normal-weight women), gallbladder (3.5 times higher risk), cervix (two times higher risk), ovary (1.6 times higher risk), and breast cancer (1.5 times higher risk) (22). Based on a five-year follow-up of 42,000 women from Iowa aged 55–69 years, cancer mortality was twofold among those with a waist:hip ratio in the fifth quintile compared with those in the lowest quintile (18). Neoplasms accounted for 50% of deaths in that study. In a 33-year follow-up of 3000 men aged 39–59 in California, cancer mortality was highest in those with a high waist-to-calf obesity index (6). Cancer mortality accounted for 31% of all deaths in this cohort.

A possible mechanism for the relationship between high body weight and cancer, discussed in the WCRF (95), relates to the metabolic abnormalities (metabolic syndrome) that result from high BMI levels. This physiological milieu promotes cell growth in general and especially that of tumor cells—because of their differential capacity to use glucose and also because of their up-regulation of receptors for the insulin-like growth factor. Increased levels of bioavailable endogenous estrogen in abdominally obese women may lead to an increased risk of breast cancer (73, 74). Stoll argues, in a review of this topic, that weight reduction combined with a program of physical exercise might reduce both estrogen and insulin concentrations and thereby inhibit the development of postmenopausal breast cancer (83).

Obesity might also influence cancer detection. Obese women are more reluctant than normal-weight women to participate in cervical and breast cancer screening programs (91). Late identification of tumors decreases the chance of therapeutic success (91). Also, the presence of abundance of fat might itself complicate the detection of a tumor during mammographic screening (36). Furthermore, underlying lifestyle factors related to obesity may also play a direct role. Physical activity would promote the access of toxins through the gastroenterologic system, which has a relatively protective effect. Exposure time of toxins in the GI tract is shorter in individuals who are physically active. Dietary practices among obese individuals might predispose to cancer risk. The WCRF panel estimated that 30%–40%

of all cancers are attributable to inappropriate diet, lack of physical activity, and high body weight (95).

OBESITY AND CARDIOVASCULAR DISEASES

Kannel has stated that no risk factor has as strong an impact on the cardiovascular risk profile as obesity (38). Obesity was identified as a risk factor for CVD not long after it was identified as as mortality risk factor. Abdominal adiposity in particular is associated with CVD risk (14, 42, 67). Obesity is a risk factor for increased blood pressure and unfavorable lipid profile decreased high-density lipoprotein (HDL) cholesterol level and increased low-density lipoprotein cholesterol and triglyceride levels (13) and—as discussed in the next section—for CVD risks resulting from diabetes. Weight loss has been shown to improve blood pressure and lipid levels, at least for the short term (1, 12). Increased blood pressure or unfavorable lipid levels are related to CVD (87, 88). However, obesity also is directly related to CVD independent from blood pressure and lipid levels (32). That is, when adjustments are made for blood pressure and cholesterol levels, the relationship between obesity and CVD is attenuated, but relative risks remain high and significant (14, 80). Manson et al (53) and Shaper et al (80) argue that it may be inappropriate to adjust for blood pressure and cholesterol levels when the question is to what extent obesity adversely affects cardiovascular risk profiles, as these variables are in the causal chain between obesity and CVD. The relationship of low body weight and weight loss with CVD and the confounding effects of smoking are other explanations for observations of lower relative risks or absent relationships between high body weight and CVD (39, 53).

Figure 3 shows that age-adjusted relative risk for incident coronary heart disease (CHD) among men and women was higher than the relative risk of high BMI for mortality. US women from the Nurses' Health Study (52) with BMI above 30 kg/m^2 had a threefold risk of developing nonfatal myocardial infarction compared with women with a BMI below 21 kg/m^2 (Figure 3). Among men in the Health Professionals Study (69), those with a BMI between 29 and 33 kg/m^2 had a twofold risk and those with BMI higher than 33 kg/m^2 had a threefold risk of developing CHD compared with men with a BMI below 23 kg/m^2 (Figure 4). Among these men and women, high BMI was also related to the onset of stroke (68, 89). The Nurses' Health Study reported that high BMI levels were especially related to the onset of ischemic stroke. Hemorrhagic strokes, which occurred less often than ischemic strokes, seemed to be less common in those with high BMIs compared with those whose BMIs were low (68). Refer to Tables 2 and 3 for characteristics of the Nurses' Health Study and Health Professionals Follow-Up Study.

Framingham data, based on 26 years of follow-up of approximately 5200 men and women aged 28–62, showed that high relative weights were predictive of myocardial infarction, sudden death, congestive heart failure, and atherothrombic

strokes. Most correlations were found among men and women younger and older than 50 years. Myocardial infarction in women over 50 years old and stroke in men over 50 years old were not excessive in the upper categories of relative weight (32). The British Regional Heart Study of 7700 men aged 40–59 years, followed for a mean period of 14.8 years, showed that high BMI levels were related to incident coronary heart events and, although to a lesser extent, stroke (80).

It was estimated from the Framingham Study data that if everyone could be kept at optimal weight, there would be 25% less CHD and 35% fewer strokes or episodes of heart failure (32). A 20% weight reduction in the obese should confer a 40% reduced risk of a coronary event (32).

OBESITY AND TYPE 2 DIABETES MELLITUS

Besides being the major risk factor for CVD, obesity, in particular abdominal obesity, is the most important risk factor in the onset of type 2 diabetes. In the Nurses' Health Study (5) and the Health Professionals Follow-Up Study (7), it was found that compared with the lowest BMI category, risks for developing type 2 diabetes mellitus were increased more than tenfold among women with BMIs higher than 29 kg/m^2 and among men with BMIs larger than 31 kg/m^2 (Figures 3 and 4). Also, being moderately overweight was closely related to the onset of type 2 diabetes mellitus. Weight loss of more than 4% during the first 5 years of follow-up showed a 1.5 times reduced risk of developing type 2 diabetes among British men aged 40–59 years, followed for a mean period of 16.8 years, compared with men with stable weight. Weight loss reduced the risk of type 2 diabetes by a factor of around 2.5 compared with those who gained weight more than 10% (90).

The WHO has calculated that about 64% of type 2 diabetes in US men and 74% in US women could be avoided if there were no BMIs above 25 kg/m^2 (7, 11, 92). The WHO also predicted that the number of diabetics would double from 143 million in 1997 to about 300 million in 2025 (79, 93). In Asian countries, the prevalence of type 2 diabetes mellitus will increase more rapidly over time than the increase in obesity (79). King et al (40) calculated that in 2025, India and China, together with the United States, will be the countries with the largest numbers of diabetics.

Concentrations of free fatty acids are excessive in individuals with abdominal obesity and amplify insulin resistance (3). In his Banting Lecture in 1988, Reaven (66) suggested a direct relationship between plasma insulin concentration and blood pressure. Thus, he raised the possibility that insulin-stimulated glucose uptake and hyperinsulinemia are involved in the etiology and clinical course of three major related disease: type 2 diabetes, hypertension, and coronary artery disease (66). Björntorp subsequently described abdominal obesity as an integral part of this disease cluster (3). Ferrannini et al recognized hyperinsulinemia as the key feature in this clustering of diseases, from their study of 2930 Mexican-Americans

and non-Hispanic whites from San Antonio, Texas (15). From an analyses of 515 European men aged 38 years old, Cigolini et al (8) argued that obesity and abdominal fat distribution were even more correlated than was hyperinsulinaemia to unfavorable risk profiles for CVD (increased total cholesterol, decreased HDL cholesterol, decreased HDL cholesterol, and high blood pressure levels).

The clustering of the major cardiovascular risk factors, abnormal glucose metabolism, an unfavorable lipid profile, hypertension, and abdominal obesity were later described as syndrome X, the deadly quartet, and the metabolic syndrome (3, 15).

OBESITY AND MUSCULOSKELETAL DISORDERS

Obesity is one of the most important preventable risk factors of osteoarthritis in knee and hip joints, and osteoarthritis, in turn, is an important risk factor for disability (63). Osteoarthritis is more common among women than among men. The relationship between being overweight and having osteoarthritis is explained, at least in part, by the high joint pressure in overweight individuals. There might also be a metabolic explanation, because obesity also seems to be related to incident osteoarthritis in the hands (63). A case-control study by Oliveria et al found odds ratios of incident osteoarthritis between 1990 and 1993 of 3.0 and 10.5, respectively, for women aged 20–80 years who were in the highest tertiles of BMI compared to the lowest.

Associations between obesity and herniated lumbar intervertebral disc, low back pain, and chronic neck pain have been suggested, but these associations are less strong than for osteoarthritis and are based on cross-sectional studies (28, 47, 51). Longitudinal studies of these associations are needed to confirm these associations.

OBESITY AND WORK DISABILITY

In most European countries, in cases of work disability and sick leave, pensions are, at least partly, reimbursed. Therefore, data on the relationship between obesity and work disability come mainly from European studies. In Finland, disability pensions were granted 2.0 and 1.5 times more often to obese men and women, respectively, compared with those with low BMIs (71). This study was based on a National Survey sample of 31,000 Finns who were followed from 1966–1972 until 1982 (Figure 5). Of 1300 obese Swedish women aged 30–59 years, 12% were recorded to have disability pensions compared with 5% of the general population, and the obese women reported 1.5–1.9 times more sick leave during a 1-year period compared with the normal Swedish population (59).

Obesity is also related to mobility limitations, which affect quality of life particularly with aging. Limitations in daily activities requiring mobility occurred twice as often among US women with a mean age of 65 who were in the highest BMI

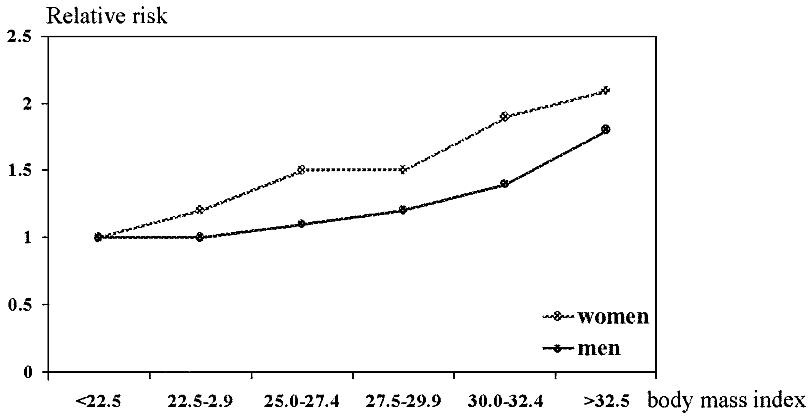

Figure 5 Risk of work disability due to being overweight in a Finnish population. Body mass index below 22.5 kg/m^2 was taken as the reference. Relative risks were adjusted for age, geographical region, smoking habits, and occupation. Data were derived from Rissanen et al (71).

tertile compared with those in the lowest tertile, i.e. approximately 5% during the 4-year follow-up (43). Self-reported onset of difficulties in walking and climbing a flight of stairs occurred 2.3 times more often in the obese among a population with mainly African Americans and Mexican Americans aged 51–61 years, with an overall incidence rate of 6% during a 2-year follow-up (9). The role of musculoskeletal disorders in the causal chain between being overweight and having a disability should be further assessed.

OBESITY AND RESPIRATORY DISORDERS

During the past decade, the role of excess fat became known as an obesity-related public health problem because of its link with shortness of breath and sleep apnea. Based on a sample of Dutch adults aged 20–59 years (45), the odds ratios for shortness of breath when walking upstairs in those with a BMI of 30 kg/m^2 or higher were 3.5 in men and 3.3 in women compared with those with BMIs below 25 kg/m^2. Furthermore, obese patients are more likely to experience obstructive sleep apnea and concurrent psychosocial morbidity. Based on their random sample of 602 employed US men and women aged 30–60 years (96), Young et al estimated that the risk of sleep-disordered breathing was around four times more common when BMI was 5 kg/m^2 higher.

The role of bearing weight or body fat on different parts of the body on the lung function is indicated by comparing odds ratios for sleep-disordered breathing for smaller versus larger girths at different parts of the body. Comparing odds of girths of neck, waist, and hip, Young et al found that odds ratio for sleep-disordered

breathing was lowest for a large hip girth and highest for a large neck girth (96).

Hypoventilation during sleep leads to nocturnal hypoxia during sleep and extreme sleepiness during the day. It could well be that sleep apnea promotes weight gain and prevents weight loss because of visceral fat–related hormone disturbances (24).

Obesity-induced sleep apnea is an important risk factor for psychosocial morbidity and seems associated with some of the components of the metabolic syndrome (25). Young et al estimated that the sleep apnea syndrome was present in 2% of women and 4% of men (96).

OBESITY AMONG THE ELDERLY

The elderly represent a particularly important age category with respect to the public health. This age group is increasing in magnitude in industrialized societies and also in nonindustrialized societies because of the increased life expectancy associated with improved standards of living. BMI levels increase with aging until age 60–70, after which BMI decreases (62).

Changes in body composition with aging imply a change in the relationship between BMI and fatness (21) and the relationship between BMI and mortality may change concurrently. It is unclear whether the BMI is the most appropriate measurement of body weight for the elderly, because muscle mass usually decreases with aging (77). Molarius et al (58a) found promising results for the use of the waist circumference alone in a cross-sectional study on a population aged 55 years and older from Rotterdam, The Netherlands. High levels of waist circumference indicated a worsened cardiovascular risk profile in this population (58a). Which measurements of obesity are most appropriate and informative in the elderly population need clarification.

Relative risks of mortality for obesity are reported to be lower in elderly populations than in younger populations (4, 82). However, absolute prevalence rates of morbidity and disability are higher among the elderly than in younger populations. Small relative increases in morbidity and disability due to obesity will thus have a higher impact in elderly than in younger populations. In addition, living without disability is highly important for functioning and quality of life in aging (20).

COMMENTS

Obesity is related to all-cause mortality and cancer and, even more strongly, to the onset of type 2 diabetes, CVD, musculoskeletal disorders, work disability, and sleep apnea. Many of the preceding comparisons of relative risks for mortality, coronary heart disease, stroke, and diabetes were adjusted for age only, and combined never-smokers and smokers. Such comparisons, although not appropriate

for more specific purposes, suffice to provide a general impression of the impact of obesity across a spectrum of conditions.

As noted previously, the direct and indirect costs of obesity are estimated at 7% of the total health care costs in the United States (10) and around 1%–5% in Europe (72). These estimates are based on prevalence rates and relative risks. Because of its closer relationship to morbidity and disability than mortality, obesity will increase the number of unhealthy life years enormously. Oster et al (64) calculated that weight loss of about 10% of initial body weight would reduce the number of life years with hypertension by 1.2–2.9 years, and type 2 diabetes mellitus by 0.5–1.7 years. Life expectancy would be increased by 2–7 months (64). Again, these estimates are based on calculations using relative risks for the specific outcomes. Empirical data on the number of years obese persons suffer more than normal-weight persons from morbidity and disability have yet to be published.

Nevertheless, it is clear that the public health impact of obesity is enormous and will increase rapidly with each percentage increase in the prevalence of obesity. Public health programs should include in their targets goals for reducing the obesity epidemic. Countries such as China and India are of particular importance in the obesity epidemic. In these countries, every 1 point increase in obesity prevalence involves 20 million more obese people.

The increasing obesity epidemic points to the urgent need for strategies to develop multifaceted global and national plans for adequate prevention and management of obesity (76). A reduction in obesity is among the National Health Promotion and Disease Prevention Objectives in the United States. In Europe, countries such as England have set goals for reducing obesity. However, such targets are lacking in most European countries.

Based on a study of persons aged 20–72 years, who were followed for 6 years, Russell et al (71a) concluded that prevention of weight gain would be more successful than treatment of people who are already obese. The International Task Force on Obesity, a work group of the WHO, points to several possibilities for implementing prevention programs (34). However, unfortunately, the few weight gain prevention programs reported to date have not been very successful (17, 19, 35, 85). Swinburn et al (84) describe the societal elements that influence food intake and physical activity as the "obesogenic" environment. Intervention programs should take these factors into account (35). New programs should change the prevalence of obesity during the long run by minimal changes in the energy balance.

CONCLUSION

The impact of obesity on morbidity and disability is higher than its impact on mortality. Therefore, each increase in obesity prevalence will increase obesity-related disability, not only in industrialized countries but also, on a very large scale, in industrializing countries. Weight gain prevention programs should be high on the scientific and political agendas.

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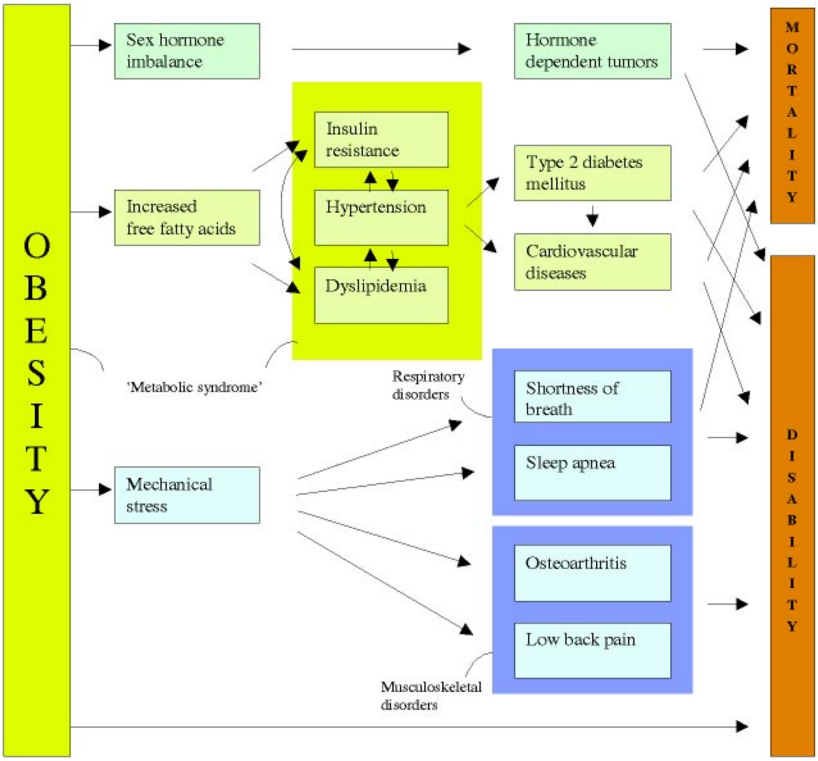

Figure 1 The public health impact of obesity.

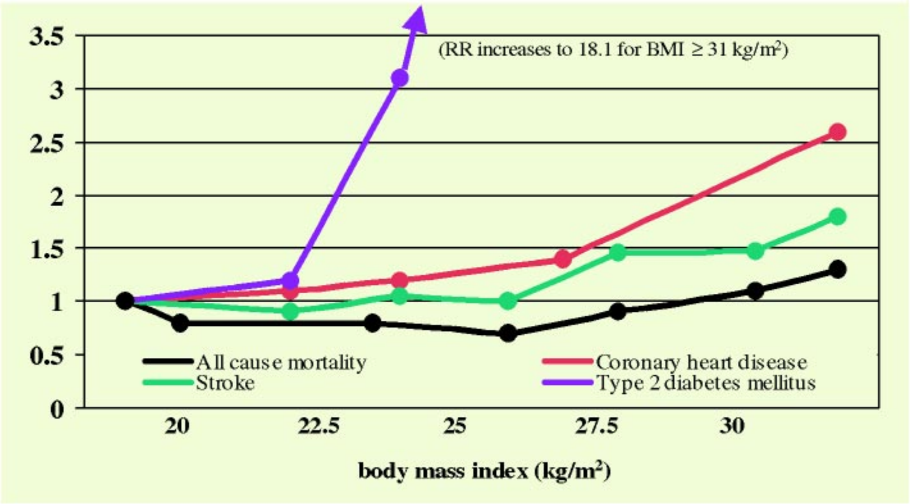

Figure 3 Age-adjusted relative risks by categories of body mass index for different endpoints among US women from the Nurses' Health Study.

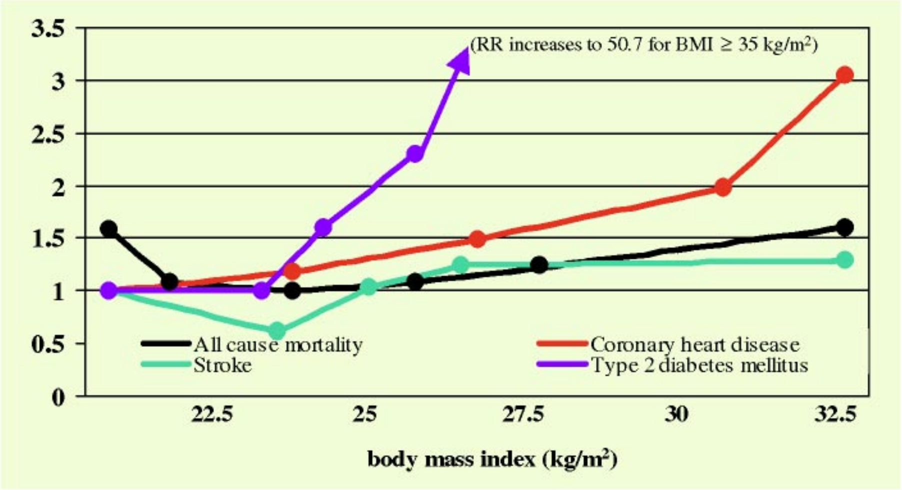

Figure 4 Age-adjusted relative risks by categories of body mass index for different endpoints among US men from the Health Professonals Study.

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CONTENTS