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Epidemiology of Obesity and Diabetes

Prevalence and Trends

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INTRODUCTION

Overweight and obesity have reached epidemic proportions globally along with an adoption of a westernized lifestyle characterized by a combination of excessive food intake and inadequate physical activity. In the United States, the prevalence of obesity doubled during the past two decades, and currently 30% of the US adult population is classified as obese. An additional 35% of US adults are overweight but not obese. Children and adolescents are not immune to the epidemic. Among US children and adolescents, 16% are overweight and an additional 15% are at risk of overweight.

The dramatic rise in the prevalence of obesity and changes in lifestyle-related factors such as a reduction in physical activity have been accompanied by alarming increases in the incidence and prevalence of type 2 diabetes. It has been estimated that the total number of adults with diabetes (mainly type 2 diabetes) will approximately double between 2000 and 2030, from 171 million to 366 million (1). The epidemic proportions of the disease are particularly noticeable in indigenous populations that have undergone rapid acculturation from their traditional lifestyles.

Considering the tremendous economic and human costs associated with obesity and diabetes, public health intervention programs aiming at preventing these two diseases are urgently needed.

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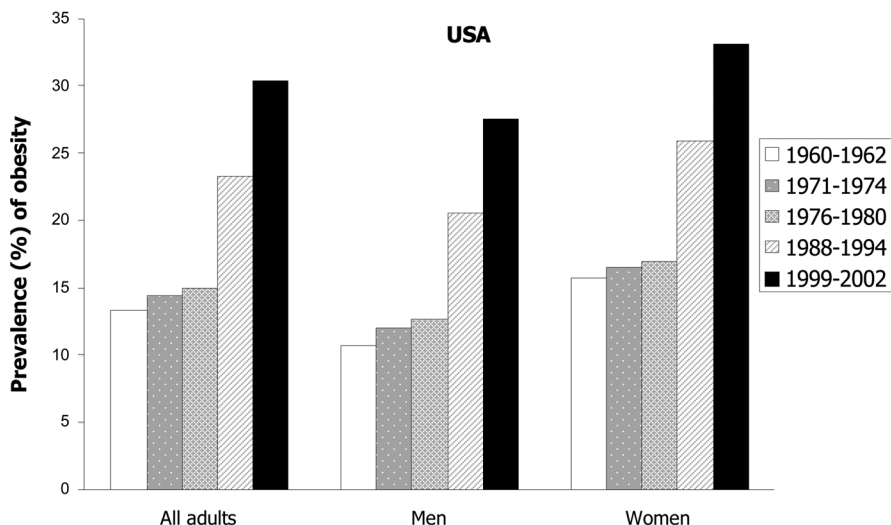


Fig. 1. Time trends in prevalence (%) of obesity (body mass index ≥ 30.0 kg/m²) in adults (ages 20–74 yr) in the United States, 1960–2002. The data are from NHES I (1960–1962) and NHANES (1971–1974, 1976–1980, 1988–1994, 1999–2002) (3,4).

This chapter presents the prevalence, secular trends, and geographic distribution of overweight, obesity, and diabetes in adults, children, and adolescents in the United States and in other developed countries as well as in developing countries. In addition, it briefly summarizes the epidemiological literature on obesity, weight gain, weight loss, and physical activity in relation to the risk of developing diabetes.

PREVALENCE AND TRENDS OF OBESITY IN ADULTS

Overweight in adults has been defined as a body mass index ([BMI]; the weight in kilograms divided by the square of height in meters) of 25.0–29.9 kg/m² and obesity as a BMI of 30.0 kg/m² or higher, in accordance with World Health Organization (WHO) recommendations (2). Even though the same classifications for overweight and obesity have been used in the studies summarized here, these studies may not be directly comparable because of differences in methods (measured or self-reported weights and heights) and periods of data collection (secular trends). Other issues include representativeness of samples (limited geographic area or national, urban, or rural), sample size, age, and sex.

United States, Canada, and Latin America

Estimates of the prevalence and time trends of obesity in the United States are based on data from the National Health and Nutrition Examination Survey (NHANES), which includes nationally representative samples of the US civilian noninstitutionalized population. The surveys include the first National Health Examination Survey (NHES I); the first, second, and third NHANES surveys; and a continuous survey that began in 1999 (3,4). Height and weight were measured in a mobile examination center using standardized techniques and equipment. As shown in Fig. 1, the prevalence of obesity among adults ages 20–76 yr was relatively constant from 1960 to 1980, then increased steeply. Comparison of the period 1976–1980 with 1999–2002, reveals that the prevalence of overweight (BMI ≥ 25 kg/m²) increased by about 40% (from 47 to 65%) and

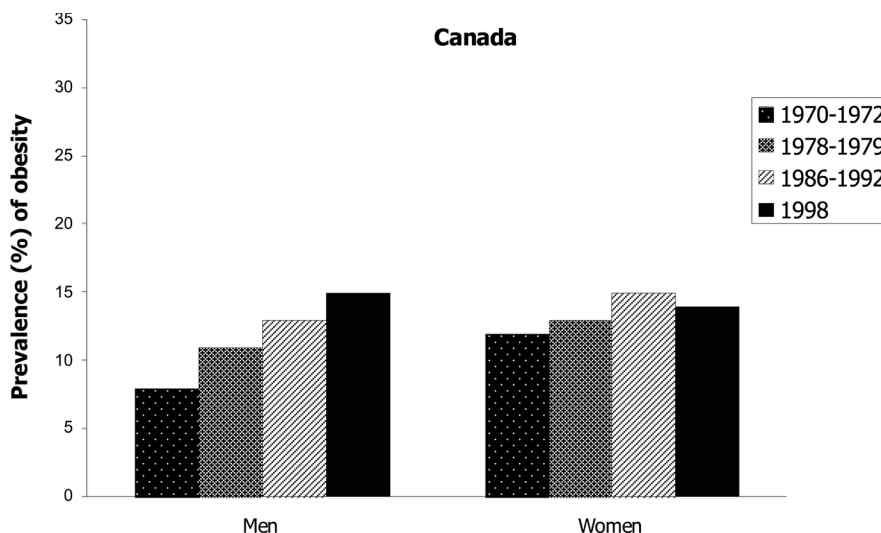


Fig. 2. Time trends in prevalence (%) of obesity (body mass index ≥ 30.0 kg/m²) in adults (ages 20–64 yr) in Canada, 1970–1998. The data are from Nutrition Canada Survey (1970–1972), Canada Health Survey (1978–1979), Canada Heart Health Surveys (1986–1992), and National Population Health Survey (1998) (5).

the prevalence of obesity (BMI ≥ 30 kg/m²) rose by 100% (from 15 to 30%). Regarding extreme obesity (BMI ≥ 40 kg/m²), the prevalence rose from 3% in 1988–1994 to 5% in 1999–2002. The increases in overweight and obesity have occurred in all age and racial/ethnic groups. In 1999–2002, the highest prevalence of overweight and obesity was found among non-Hispanic black women (77%).

The prevalence of obesity in Canada is lower than in the United States, but it appears to increase over time. Data from national surveys in Canada (5) showed that between 1970–1972 and 1998, the prevalence of obesity in adults (ages 20–64 yr) increased from about 8 to 15% in men and from 12 to 14% in women (Fig. 2).

Three national surveys were conducted in the two most populated Brazilian regions in 1975, 1989, and 1997 (6). Between 1975 and 1997, the prevalence of obesity among adults over 20 yr of age increased from 2.4 to 6.9% in men and from 7.0 to 12.5% in women (Fig. 3). The most recent trend, from 1989 to 1997, indicated that the increases in obesity prevalence were more intense in men than in women, in rural than in urban settings, and in poorer than in richer families. There was a reduction in the prevalence of obesity among upper-income urban women (12.8–9.2%).

Fernald et al. (7) assessed the prevalence of overweight and obesity among the rural poor in Mexico in comparison with a national sample using data from two national surveys in Mexico. The first survey was conducted in 2000 in about 45,000 adults and was based on a nationally representative sample of the Mexican noninstitutionalized population. The second survey was conducted in 2003 in about 13,000 adults and was designed to be representative of the poorest rural communities in seven Mexican states. In both surveys, height and weight were measured using standardized techniques. In the nationally representative sample, the prevalence of overweight and obesity was 40.8 and 20.4%, respectively, in men. The corresponding figures in women were 36.5 and 30.2%, respectively. In the 2003 sample from low-income rural regions of Mexico, the prevalence of overweight and obesity was 38.9 and 13.6% in men, and 36.8 and 22.2% in women.

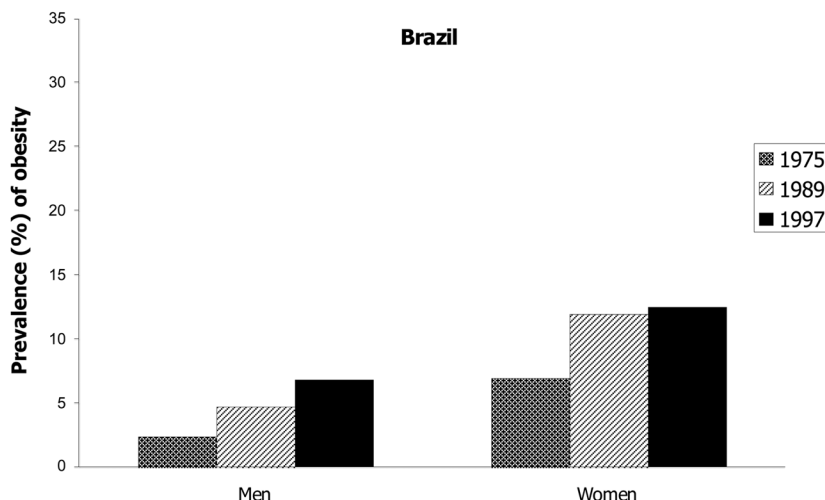


Fig. 3. Time trends in prevalence (%) of obesity (body mass index ≥ 30.0 kg/m²) in adults (ages 25–64 yr) in Brazil, 1975–1997. The data are from national household surveys in northeast and southeast Brazil (6).

Europe

The Monitoring Trends and Determinants in Cardiovascular Disease (MONICA) Project includes a series of cross-sectional surveys in 26 countries, mostly in Europe (8). In each survey a random sample of at least 200 persons ages 35–64 yr was selected. Standardized methods were applied for anthropometric measurements. Table 1 shows the age-standardized prevalence of obesity in the European countries included in the MONICA Project. Overall, the prevalence of obesity increased in most European populations over the 10-yr study period. In the last survey (in the early 1990s), the prevalence of obesity in the populations varied from approx 15 to 25% in men and 10 to 35% in women, with the highest prevalence in men and women from Eastern Europe. Among women, there was a significant inverse association between educational level and BMI in virtually all 26 countries; the difference in mean BMI between the highest and lowest educational tertiles ranged from -3.3 to -0.6 kg/m² in the 1990s. Among men, the association between BMI and educational level was positive in some Eastern and Central European populations and in China and also in populations with a low prevalence of obesity. By contrast, there was an inverse association between BMI and educational level in populations with a high prevalence of obesity.

Table 2 provides other national survey data from European populations. In Finland, the proportion of obese men doubled between 1972 and 1997 (9), whereas the prevalence of obesity in women remained constant over the 25-yr period. The most recent data show that about 20% of men and women in Finland are obese (9). Between the 1980s and 1990s, considerable increases in the prevalence of obesity have occurred in both men and women in Norway (10), the Netherlands (11), Sweden (12), and the United Kingdom (13) and in men in France (14).

Africa

Using data from nationally representative surveys conducted in the 1990s, the overall proportion of obese women (ages 15–49 yr) in sub-Saharan Africa was estimated to be 2.5%, ranging from 1.0% in Burkina Faso to 7.1% in Namibia (15). The proportion of

Table 1
Prevalence of Obesity (BMI ≥ 30.0 kg/m²) in MONICA Populations
Ages 35–64 yr in Early 1980s and Early 1990s^a

Area	Country, center	Men (%)		Women (%)	
		1980s	1990s	1980s	1990s
Northern Europe	Denmark, Glostrup	11	13	10	12
	Finland, Kuopio Province	18	24	19	26
	Finland, North Karelia	17	23	24	24
	Finland, Turku-Loimaa	19	22	17	19
	Iceland, Iceland	11	16	11	18
	Sweden, Gothenburg	7	13	9	10
	Sweden, Northern Sweden	11	14	14	14
Western Europe	United Kingdom, Belfast	11	14	14	16
	United Kingdom, Glasgow	11	23	16	23
	Germany, Augsburg	18	17	15	21
	Germany, Augsburg, rural	20	24	22	23
	Germany, Bremen	14	16	18	21
	Belgium, Ghent	11	13	15	16
	France, Lille	14	17	19	22
	France, Strasbourg	22	22	23	19
	France, Toulouse	9	13	11	10
	Switzerland, Ticino	20	13	15	16
	Switzerland, Vaud-Fribourg	13	17	13	10
Eastern Europe	Russian Federation, Moscow	13	8	33	22
	Russian Federation, Novosibirsk	14	17	44	35
	Lithuania, Kaunas	22	20	45	32
	Poland, Warsaw	18	22	26	29
	Poland, Tarnobrzeg Voivodship	13	15	32	36
	Czech Republic, Czech Republic	21	23	32	30
Southern Europe	Spain, Catalonia	9	16	24	25
	Italy, Area Brianza	11	14	15	18
	Italy, Friuli	16	17	19	19

^aAdapted from ref. 8.

obese women was greater in urban than in rural regions (Fig. 4). Furthermore, in general, obesity was more frequent among women with a high educational level than among women with a low educational level. This is in contrast to the Western countries with a high prevalence of obesity, where an inverse relation between educational level and BMI in women has been observed.

Asia, Western Pacific, and India

Despite an increasing prevalence of overweight and obesity in Asia, the prevalence remains low (Table 3). Based on nationwide cross-sectional surveys conducted in Japan (16), the proportion of overweight and obese men increased from 14.5 and 0.8%, respectively, in the time period 1976–1980 to 20.5 and 2.0% during 1991–1995. The increasing trend was most apparent in the youngest age groups (20–29 yr) and in those from small towns. In women, the prevalence of overweight and obesity remained relatively constant over this 20-yr period, although a decreasing prevalence was noted in

Table 2
Prevalence of Obesity (BMI ≥ 30.0 kg/m²) in Men
and Women in Selected European Countries

Country	Period	Age (yr)	Men (%)	Women (%)	Reference
Finland	1972	25–59	10.1	19.2	9
	1977	25–59	12.3	20.6	
	1982	25–59	14.9	18.7	
	1987	25–59	17.7	20.6	
	1992	25–59	19.9	21.3	
	1997	25–59	20.7	20.1	
France	1985–1987	35–64	10	11	14
	1995–1997	35–64	13	11	
Norway	1984–1986	≥ 20	7.5	13.0	10
	1995–1997	≥ 20	14.0	17.8	
The Netherlands	1976–1980	37–43	4.9	6.2	11
	1987–1991	37–43	7.4	7.6	
	1993–1997	37–43	8.5	9.3	
Sweden	1980/1981	16–84	6.6	8.8	12
	1988/1989	16–84	7.3	9.1	
	1996/1997	16–84	10.0	11.9	
United Kingdom	1987/1989	≥ 16	7	12	13
	1993	≥ 16	13	16	
	1994	≥ 16	14	17	
	1995	≥ 16	15	17	
	1996	≥ 16	16	18	
	1997	≥ 16	17	19	

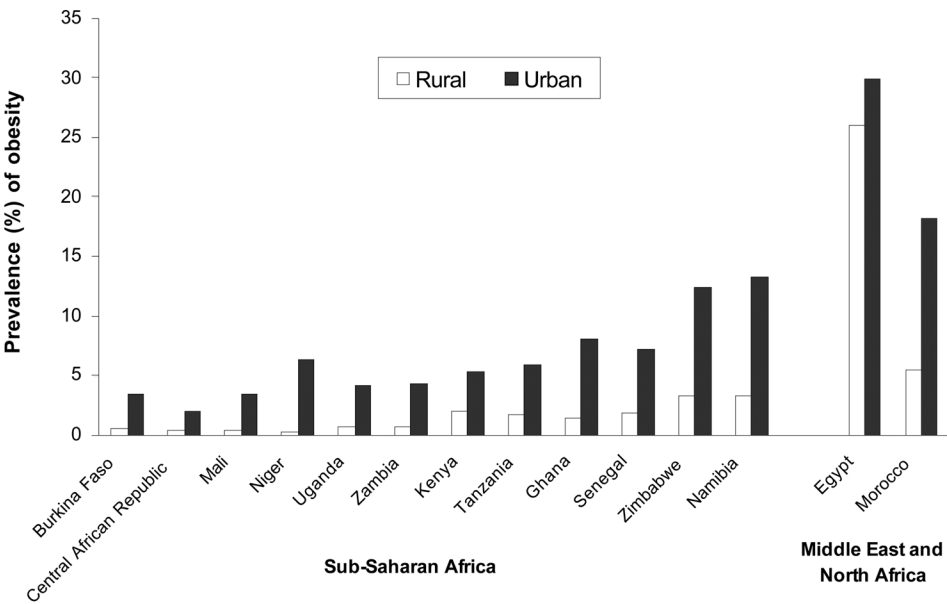


Fig. 4. Prevalence (%) of obesity in women (ages 15–49 yr) in Africa and Midle East in 1990s by rural and urban area. (From ref. 15.)

Table 3
Prevalence of Obesity (BMI \geq 30.0 kg/m²) in Men and Women in Asia,
Western Pacific Regions, and India

<i>Country</i>	<i>Period</i>	<i>Age (yr)</i>	<i>Men (%)</i>	<i>Women (%)</i>	<i>Reference</i>
India					
Urban (Delhi)	1991–1995	35–64	7.1	16.4	20
Rural (Haryana)	1991–1995	35–64	0.7	2.2	
China	1989	20–45	0.4	0.2	17
	1997	20–45	0.5	1.5	
Japan, national surveys	1976–1980	\geq 20	0.8	2.3	16
	1981–1985	\geq 20	1.1	2.3	
	1986–1990	\geq 20	1.5	2.2	
	1991–1995	\geq 20	2.0	2.3	
Nepal, national surveys	1996	15–49	–	0.1	15
Australia, national surveys	1980	25–64	9.3	8.0	19
	1983	25–64	9.1	10.5	
	1989	25–64	11.5	13.2	
New Zealand, national surveys	1989	18–64	10	12	18
Papua New Guinea					
Urban coastal	1991	25–69	36	54	21
Rural coastal	1991	25–69	24	19	
Highlands	1991	25–69	5	5	
Samoa					
Urban	1978	25–69	39	59	21
	1991	25–69	58	77	
Rural	1978	25–69	18	37	
	1991	25–69	42	59	
Nauru	1987	25–69	65	70	21

younger women (ages 20–29 yr). Data from the China Health and Nutrition survey, showed that between 1989 and 1997, the prevalence of overweight almost doubled in women (from 10.3 to 19.2%) and tripled in men (from 4.6 to 13.6%) (17). Regarding obesity, the prevalence increased from 0.2 to 1.5% in women and from 0.4 to 0.5% in men over the same time period. However, there are Asian nations, such as Nepal, where the prevalence of obesity is very low (0.1% in women in 1997) (15).

In Australia and New Zealand, the prevalence of obesity was 10–13% in the late 1980s (Table 3) (18,19). Results from national surveys in Australia indicated that the proportion of obese persons increased over a 9-yr period, from about 8 to 9% in 1980 to 12 to 13% in 1989 (19). Cross-sectional surveys conducted in India in 1991–1995 (20) revealed a considerably higher prevalence of obesity in urban (7.1% in men and 16.4% in women) than in rural (0.7 in men and 2.2% in women) regions (Table 3).

Finally, there is a very high prevalence of obesity in Polynesian populations, with up to 65% of men and 80% of women being obese (21). The prevalence of obesity in Polynesian populations is higher in urban than in rural areas. Since the late 1980s, the prevalence of obesity has increased markedly in these populations (21).

Summary

The prevalence of obesity has markedly increased during the last few decades in the United States and other countries. Specifically, between the periods 1976–1980 and

Table 4
International Cutoff Points for BMI for Overweight and Obesity
by Sex Between Ages 2 and 18 yr^a

Age (yr)	Overweight (kg/m ²)		Obesity (kg/m ²)	
	Males	Females	Males	Females
2	18.4	18.0	20.1	19.8
4	17.6	17.3	19.3	19.2
6	17.6	17.3	19.8	19.7
8	18.4	18.4	21.6	21.6
10	19.8	19.9	24.0	24.1
12	21.2	21.7	26.0	26.7
14	22.6	23.3	27.6	28.6
16	23.9	24.4	28.9	29.4
18	25.0	25.0	30.0	30.0

^aAdapted from ref. 24.

1999–2002, the prevalence of obesity doubled among US adults, and currently about one-third of the US adult population is obese (3,4). The obesity epidemic will tremendously affect public health, because obesity is strongly associated with several chronic diseases, including cardiovascular disease, type 2 diabetes, and certain cancers. Because these conditions can be costly to treat, obesity clearly has a considerable economic impact. Obesity-related morbidity has been estimated to account for 5.5–7.8% of total health-care expenditures in the United States (22).

PREVALENCE AND TRENDS OF OBESITY IN CHILDREN AND ADOLESCENTS

Currently, there is a lack of agreement concerning the definitions for overweight and obesity in children and adolescents, which makes comparisons of prevalence across countries difficult. In the United States, the 85th and 95th percentiles of BMI for age and sex based on nationally representative survey data have been recommended as cutoff points to identify overweight and obesity (23). The European Childhood Obesity Group of the International Obesity Task Force (IOTF) (24) has proposed an international reference, age- and sex-specific BMI cutoff points, to define childhood and adolescent overweight and obesity. The IOTF reference was developed based on data from measured children and adolescents, ages 6–18 yr, across six heterogeneous nations: Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States. The IOTF definitions of overweight and obesity presented in Table 4 are based on age- and sex-specific BMI cutoff points corresponding to a BMI of 25 and 30 kg/m², respectively, at age 18 (24).

United States and Canada

Six nationally representative examination surveys on the prevalence of overweight among children and adolescents have been conducted in the United States between the 1960s and 1999–2002: NHES 2 and 3; NHANES I, II, and III; and the continuous NHANES (4,25,26). The same standardized measurements have been used in all surveys, thus allowing a unique and comprehensive examination of the changes in overweight status. The 2000 Centers for Disease Control and Prevention growth charts for the

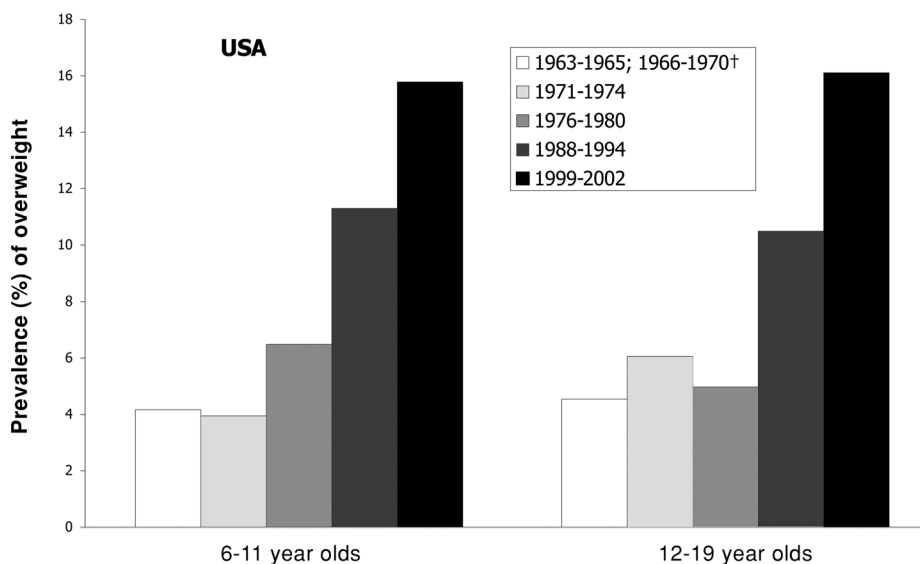


Fig. 5. Time trends in prevalence (%) of overweight (body mass index for age at 95th percentile or greater) in children and adolescents in national surveys in United States, 1963–2000. †Data for 1963–1965 are for children 6–11 yr of age; data for 1966–1970 are for adolescents 12–17 yr of age, not 12–19. The data are from NHES 2 (1960–1965), NHES 3 (1966–1970), and NHANES (1971–1974, 1976–1980, 1988–1994, 1999–2002) (4,25,26).

United States were used to define overweight and at risk for overweight among children (23). The BMI-for-age growth charts were developed from five of those six national surveys (NHES 2 and 3, NHANES I and II, and NHANES III for children younger than 6 yr of age). At risk for overweight was defined as a BMI at or above the 85th percentile but less than the 95th percentile of the sex-specific BMI, as defined by the growth chart. Overweight was defined as at or above the 95th percentile of the sex-specific BMI-for-age growth chart. Between the 1960s and 1999–2002, the prevalence of overweight among 6- through 11-yr-old children increased from 4.2 to 15.8% (Fig. 5). During this same period, the corresponding prevalence among 12- through 19-yr-old children increased from 4.6 to 16.1%. Among children 2 through 5 yr old, a doubling in the prevalence of overweight was noted between 1971–1974 and 1999–2002 (from 5.0 to 10.3%). The most recent data (1999–2002) further show that another 15% of children and teens ages 6–19 yr and 12% of children ages 2–5 yr are considered at risk of becoming overweight.

The prevalence of overweight in children and adolescents in Canada has also been dramatically increasing. Willms et al. (27) assessed the prevalence of overweight and obesity among Canadian boys and girls ages 7–13 yr. Overweight and obesity were defined according to the reference proposed by the IOTF (24). The results revealed that over a 15-yr period the proportion of overweight Canadian children increased almost threefold, from 11.4% in 1981 to 29.3% in 1996. The prevalence of overweight was highest in children and adolescents with low socioeconomic status.

Europe

Lissau et al. (28) summarized the prevalence of overweight among adolescents in 13 European countries and the United States using data from nationally (or regionally for

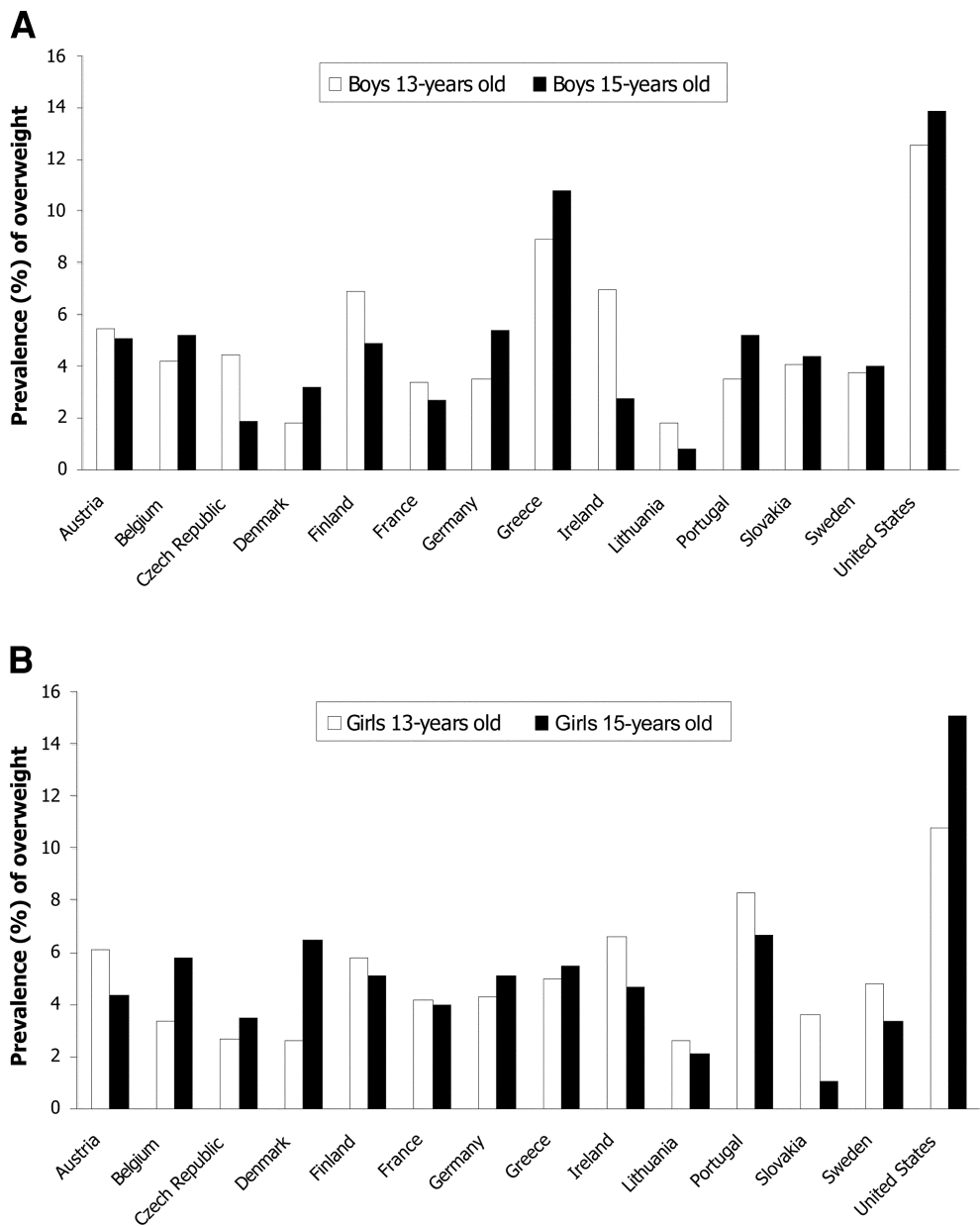


Fig. 6. Prevalence of overweight (body mass index at or above 95th percentile) in (A) in boys and (B) girls in 13 European countries and United States in 1997–1998. (From ref. 28.)

Flemish Belgium and France) representative, cross-sectional 1997–1998 school-year surveys that used identical data collection methods. At least 1540 adolescents were included from each country. Data for BMI were based on self-reported weights and heights; these data were also used to create a reference curve (based on all 29,242 adolescents) to establish cutoff points for BMI at or above the 95th centile, defined as overweight. The prevalence of overweight was highest in the United States, Ireland, Greece, and Portugal, and lowest in Lithuania (Fig. 6).

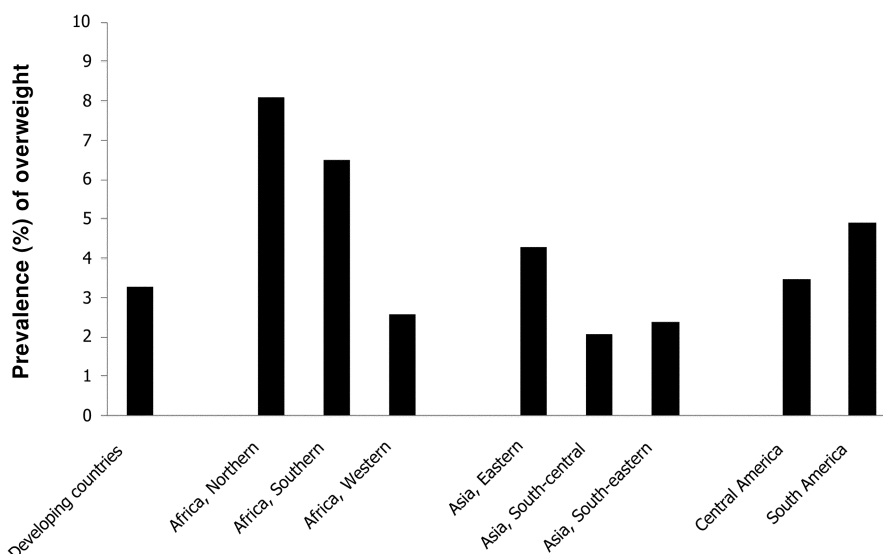


Fig. 7. Global and regional prevalence of overweight in preschool children (under 5 yr of age) in developing countries in 1995. (From ref. 29.)

Developing Countries

de Onis and Blössner (29) estimated the prevalence and trends of overweight among preschool children in developing countries by using data obtained from 160 nationally representative cross-sectional surveys (in 94 countries) included in WHO's global database on child growth and malnutrition (Geneva). The data were analyzed in a standardized way to allow comparisons across countries and over time. Estimates were obtained only for regions in which the proportion of children covered by the surveys was more than 70%. Overweight was defined as a weight-for-height two standard deviations (SDs) above the international reference median value of the National Center for Health Statistics, as recommended by WHO (30). Figure 7 presents the regional and global estimates of the prevalence of overweight children under 5 yr of age. The overall prevalence of overweight in children in this age group in developing countries in 1995 was estimated to be 3.3%. The highest prevalence was found in Latin America and the Caribbean (4.4%), followed by Africa (3.9%) and Asia (2.9%). The countries with the highest percentage of overweight children were in the Middle East (Qatar), North Africa (Algeria, Egypt, and Morocco), and Latin America and the Caribbean (Argentina, Chile, Bolivia, Peru, Uruguay, Costa Rica, and Jamaica). Other countries with a high prevalence of overweight were Armenia, Kiribati, Malawi, South Africa, and Uzbekistan. Of 38 countries for which trend data were available, 16 showed a rising trend, 8 showed a falling trend, and 14 showed no apparent change in the prevalence of overweight.

Other Survey Data

Wang et al. (31) summarized the trends of overweight in older children and adolescents ages 6–18 yr from four countries. They used nationally representative data from the United States (1971–1974 and 1988–1994), Russia (1992 and 1998), and Brazil (1975 and 1997) and nationwide survey data from China (1991 and 1997). Overweight was defined according to age- and sex-specific cutoff points recommended by IOTF (24). The overweight prevalence increased during the study periods in the United States

Table 5
Time Trends in Prevalence of Overweight in Children and Adolescents in United States, Brazil, China, and Russia According to Age, Sex, and Urban or Rural Residence^a

<i>Overweight^b</i>	<i>United States</i>		<i>Brazil</i>		<i>China</i>		<i>Russia</i>	
	<i>1971–1974</i>	<i>1988–1994</i>	<i>1974</i>	<i>1997</i>	<i>1991</i>	<i>1997</i>	<i>1992</i>	<i>1998</i>
All	15.4	25.6	4.1	13.9	6.4	7.7	15.6	9.0
Children 6–9 yr	11.8	22.0	4.9	17.4	10.5	11.3	26.4	10.2
Adolescents 10–18 yr	16.8	27.3	3.7	12.6	4.5	6.2	11.5	8.5
Males	14.5	25.0	2.9	13.1	6.3	8.4	15.5	9.6
Females	16.3	26.3	5.3	14.8	6.5	7.0	15.8	8.3
Rural	16.6	26.6	3.1	8.4	5.9	6.4	17.7	11.2
Urban	14.7	24.6	4.9	18.4	7.7	12.4	14.7	8.1

^aAdapted from ref. 31.

^bOverweight was defined as the combined prevalence of overweight and obesity. It was calculated using IOTF standards, which were age- and sex-specific BMI cutoff points corresponding to a BMI of 25 at age 25 yr (24).

(from 15.4 to 25.6%), Brazil (from 4.1 to 13.9%), and China (from 6.4 to 7.7%), but decreased in Russia (from 15.6 to 9.0%) (Table 5). The annual rates of increase in the prevalence of overweight were 0.6% in the United States, 0.5% in Brazil, and 0.2% in China. In Russia, the overweight prevalence decreased annually by 1.1%. The proportion of overweight children and adolescents in Brazil and China was higher in urban than in rural areas (Table 4).

Summary

The past three decades have seen an explosive increase in the number of overweight children in most countries of the world. Overweight and obesity in adolescence are strong determinants of obesity and related morbidity and mortality in adulthood, with 50–80% of obese adolescents becoming obese as adults (32,33). Therefore, from a public health perspective, it is of great importance to reach children and adolescents through preventive programs addressing issues of physical inactivity and dietary practices.

PREVALENCE AND TRENDS OF TYPE 2 DIABETES IN ADULTS

United States

In the United States, the most complete information on the prevalence of type 2 diabetes has been obtained from NHANES II, NHANES III, and continuous NHANES. These surveys have provided estimates of the prevalence and time trends for both diagnosed and undiagnosed diabetes, impaired fasting glucose, and impaired glucose tolerance from representative samples of the US population. According to American Diabetes Association diagnostic criteria (34), the prevalence of diagnosed and undiagnosed diabetes in US adults ages 40–74 yr increased by 38% between 1976–1980 and 1988–1994 (from 8.9 to 12.3%) (35). During the same period, the prevalence of impaired fasting glucose increased by 49% (from 6.5 to 9.7%). Based on the most recent data from NHANES, the estimated age- and sex-adjusted prevalence of diabetes (diagnosed and undiagnosed) in the total population of adults ages 20 yr and over was

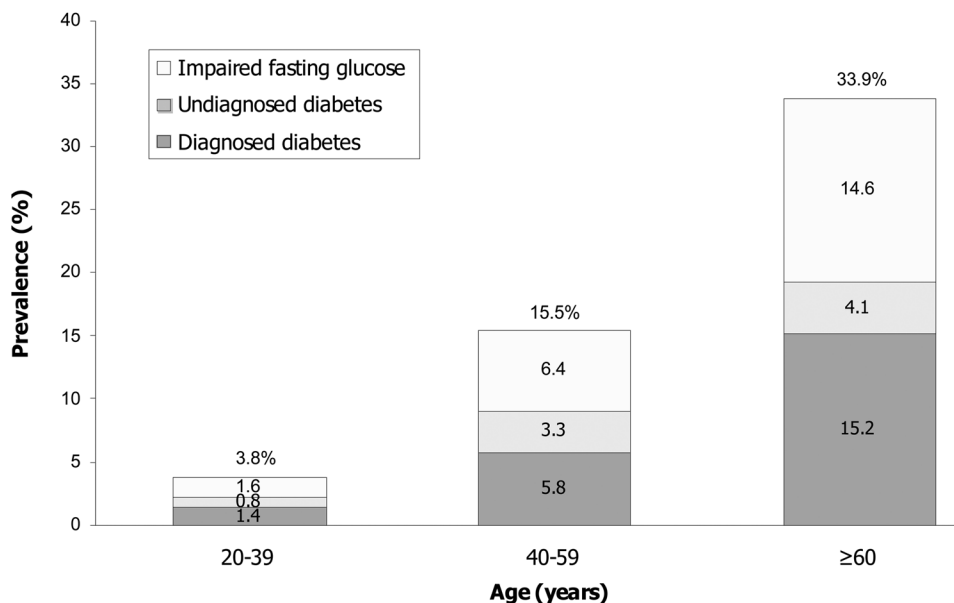


Fig. 8. Prevalence of diagnosed type 2 diabetes, impaired fasting glucose, and undiagnosed diabetes in adults ages 20 yr or over in the United States, 1999–2000. The data are from NHANES 1999–2000 (36).

8.6% in 1999–2000 (36). An additional 6.1% of adults had impaired fasting glucose, increasing to 14.6% for adults ages 60 yr and older. Overall, in 1999–2000, an estimated 14.5% of US adults 20 yr and over and 33.9% of those 60 yr and over had either diabetes or impaired fasting glucose (Fig. 8). The prevalence of diabetes and impaired fasting glucose was higher among non-Hispanic blacks (21.1% among those 20 yr and over) and Mexican Americans (18.8%) than among non-Hispanic whites (13.1%). The NHANES surveys observed that the proportion of undiagnosed diabetes represented approximately one-third of total diabetes and that this fraction has changed little over time.

Globally

Wild et al. (1) estimated the global prevalence of diabetes and the number of adults (ages 20 yr and over) with diabetes for the years 2000 and 2030. Estimates for the prevalence of diabetes by age and sex were derived from a limited number of countries and extrapolated to all 191 WHO member states and applied to United Nations population estimates for 2000 and 2030. Because most data sources did not distinguish between type 1 and type 2 diabetes, the total prevalence of diabetes was estimated. It was estimated that the prevalence of diabetes worldwide will increase by 39%, from 4.6% in 2000 to 6.4% in 2030 (Fig. 9). The prevalence is higher in developed countries than in developing countries, but the greatest relative increase in the prevalence of diabetes will occur in the developing countries in which the prevalence of diabetes is estimated to rise by 46% (from 4.1 to 6.0%). In developed countries, the prevalence is estimated to increase by 33% (from 6.3 to 8.4%). The total number of adults ages 20 yr and over with diabetes is projected to approximately double between 2000 and 2030 (from 171 million to 366 million). Overall, the prevalence of diabetes is higher in men than in women. However, more women than men have diabetes, which is most likely explained by the combined effect of a higher number of elderly women than men in

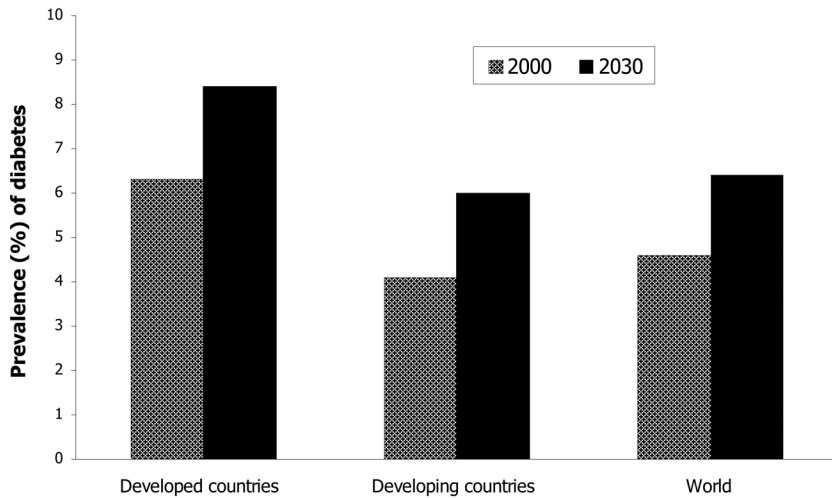


Fig. 9. Estimated prevalence (%) of type 2 diabetes in adults ages 20 yr or over in developed and developing countries and globally in years 2000 and 2030. (From ref. 1.)

Table 6
Top 10 Countries Globally With Highest Estimated Number of Adults Ages 20 yr and Over With Diabetes in 2000 and 2030^a

2000				Prediction for 2030			
Rank	Country	Adults with diabetes (millions)	Adults with diabetes (%)	Rank	Country	Adults with diabetes (millions)	Adults with diabetes (%)
1	India	31.6	5.5	1	India	79.3	8.0
2	China	20.7	2.4	2	China	42.2	3.7
3	United States	17.6	8.8	3	United States	30.2	11.2
4	Indonesia	8.4	6.7	4	Indonesia	21.2	10.6
5	Japan	6.8	6.7	8	Japan	8.9	8.8
6	Pakistan	5.2	7.7	5	Pakistan	13.8	8.7
7	Russian Federation	4.6	4.2	9	Philippines	7.8	10.2
8	Brazil	4.5	4.3	6	Brazil	11.3	7.0
9	Italy	4.2	9.2	10	Egypt	6.7	9.7
10	Bangladesh	3.2	4.6	7	Bangladesh	11.1	7.7

^aAdapted from ref. 1.

most populations and the increasing prevalence of diabetes with age. In developing countries, most adults with diabetes are in the age range of 45–65 yr, whereas in developed countries, most adults with diabetes are 65 years and above. For both 2000 and 2030, the country with the highest estimated number of adults with diabetes is India, followed by China, the United States, and Indonesia (Table 6).

Summary

The number of persons with diabetes is reaching epidemic proportions. From 2000 to 2030, the worldwide prevalence of diabetes in adults is projected to rise by 39%. The

largest proportional and absolute increase will occur in developing countries, where the prevalence will rise from 4.1 to 6.0%. In India, China, and Indonesia, the adult diabetic population is estimated to more than double by 2030. In the United States, 14.5% of adults currently have diabetes (diagnosed or undiagnosed) or impaired fasting glucose.

PREVALENCE AND TRENDS OF TYPE 2 DIABETES IN CHILDREN AND ADOLESCENTS

Previously, type 2 diabetes was mainly a disease of the middle-aged and elderly. In recent decades, however, the age at onset of type 2 diabetes has decreased, and this type of diabetes has now been reported even in children and adolescents in many populations. Type 2 diabetes has been reported in children from a number of countries, including the United States, Canada, the United Kingdom, Australia, Japan, Taiwan, and India (37). National population data on the prevalence of type 2 diabetes remain limited and are unavailable for many countries. Therefore, the precise burden of type 2 diabetes in children is still unknown. However, given the rising prevalence of overweight in children, the problem is likely to be substantial.

The largest study on diabetes in children is from Japan, with about 7 million children studied between 1976 and 1997 (38). Over the 21-yr period, the incidence of type 2 diabetes increased 10-fold in children ages 6–12 yr (0.2 per 100,000/yr from 1976 to 1980 vs 2.0 per 100,000/yr from 1991 to 1995) and almost doubled among children 13–15 yr old (7.3 vs 13.9 per 100,000/yr). However, these figures are likely to be underestimated because the initial screening step of the study was a urine glucose, with blood testing reserved only for those with glycosuria. Currently, type 2 diabetes accounts for 80% of all childhood diabetes in Japan.

Data from the United States and Canada also indicate an increasing prevalence of diabetes in children. In Cincinnati, Ohio, the annual incidence of type 2 diabetes in children and adolescents 10–19 yr old increased 10-fold between 1982 and 1994 (0.7 per 100,000 vs 7.2 per 100,000) (39). Type 2 diabetes accounted for 16% of all new diagnoses of diabetes in children up to 19 yr of age and accounted for 33% of new cases among patients ages 10–19 yr (39). In Chicago, Illinois, the 10-yr average annual incidence of type 2 diabetes among African American and Latino children and adolescents (ages 0–17 yr) increased by 9% per year from 1985 (40). Among the Cree-Ojibway aboriginals in Canada, diabetes and impaired fasting glucose were observed in 1 and 3%, respectively, of children and adolescents ages 4–19 yr (41); impaired glucose tolerance was observed in 10% of those ages 10–19 yr (42).

LIFESTYLE-RELATED RISK FACTORS FOR DIABETES

Obesity and Weight Gain

Findings from epidemiological studies have repeatedly confirmed a strong positive association between excess adiposity and risk of developing type 2 diabetes. Few risk factor–disease relationships are stronger than the link between excess adiposity and diabetes. Based on data from the Behavioral Risk Factors Surveillance System conducted in the United States, Mokdad et al. (43) estimated that for every kilogram increment in self-reported body weight, the risk for diabetes increases by about 9%. Findings from a large cohort of US men, the Health Professionals Follow-up Study, showed a 7.3% increased risk of diabetes for every kilogram of weight gained (44). Using data

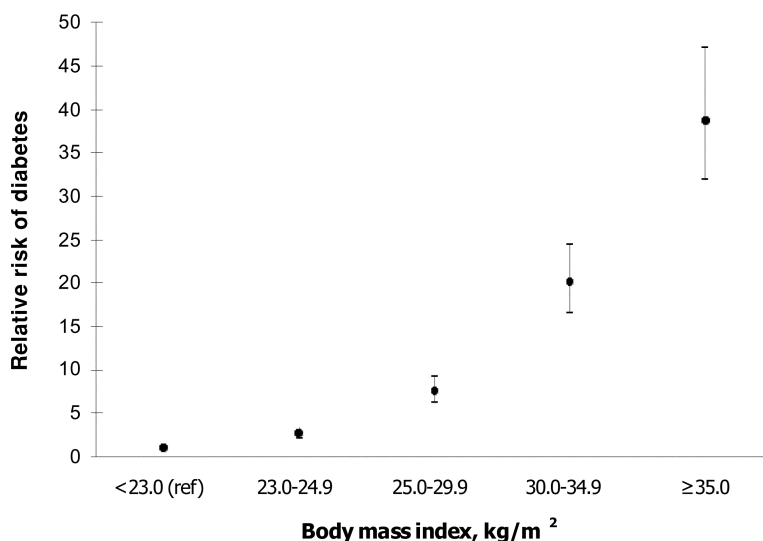


Fig. 10. Relative risk of type 2 diabetes according to body mass index in Nurses' Health Study. (From ref. 45.)

from a large cohort of women, the Nurses' Health Study, Hu et al. (45) found that overweight or obesity was the single most important determinant of diabetes, and it was estimated that approx 60% of the cases of diabetes could be attributed to overweight (BMI ≥ 25 kg/m²). Compared with women having a BMI of <23 kg/m², those with a BMI of 30–34.9 kg/m² had about a 20-fold and those with a BMI of 35 kg/m² or higher about a 40-fold increased risk of type 2 diabetes (Fig. 10) (45). Results from other studies of BMI in relation to diabetes have indicated more modest associations, with approximately six- to eightfold increased risk of diabetes among those with a BMI of 30 kg/m² or higher compared with those having a BMI <23 kg/m² (44) or <25 kg/m² (46,47). In addition to high BMI, as a measure of overall obesity, a number of studies have shown that measures of central obesity, including waist-to-hip ratio and waist circumference, are important predictors of developing type 2 diabetes (48–56). In some populations, central obesity has emerged as a better determinant of the development of type 2 diabetes than BMI (50,52–55). For example, in a population-based cohort of Dutch men and women (54), an increase of 1 SD of waist-to-thigh ratio was associated with a 42% increased risk of type 2 diabetes in men and a 92% increased risk in women, independent of BMI. After adjustment for the waist-to-thigh ratio, an increase of 1 SD of BMI was associated with a 31% increased risk of type 2 diabetes in women; BMI was not an independent determinant of risk in men (54).

Weight Loss

Evidence from epidemiological studies indicates that even moderate, sustained weight loss can increase insulin sensitivity, improve insulin action, and decrease the risk of developing type 2 diabetes. In a longitudinal study of 209 Pima Indians (57), a significant linear inverse relation was observed between changes in body weight and changes in insulin-stimulated glucose disposal in subjects with normal glucose tolerance and in those with impaired glucose tolerance. Improvements in insulin action after an average of 10% weight reduction were lost with weight regain but largely preserved with weight

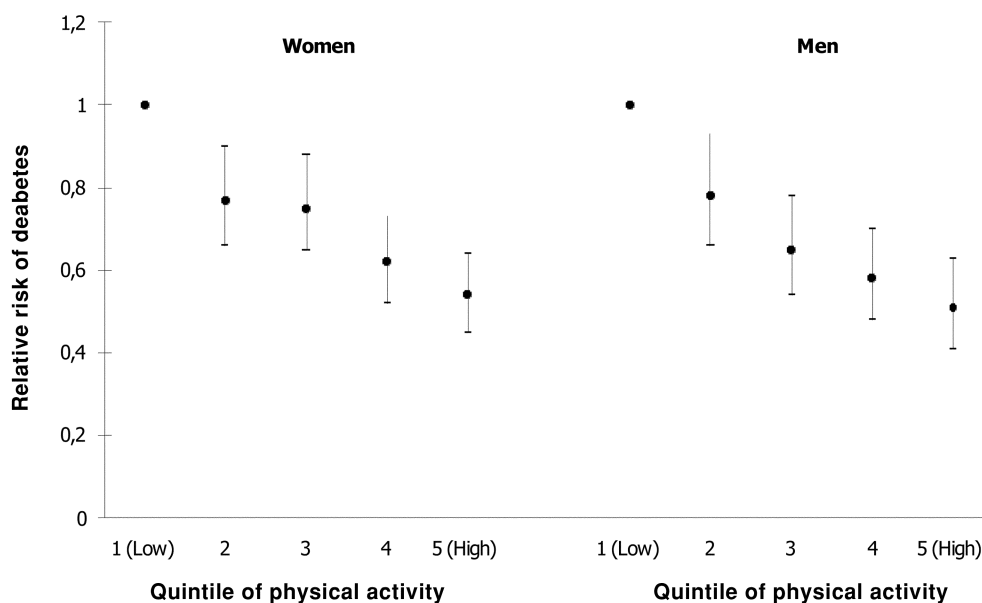


Fig. 11. Relative risk of type 2 diabetes according to total physical activity level among women in Nurses' Health Study and among men in Health Professionals Follow-up Study. (From refs. 63 and 66.)

maintenance. In the Finnish Diabetes Prevention Study (58), sustained weight reduction during a 4-yr follow-up of individuals with impaired glucose tolerance resulted in a substantial improvement in insulin sensitivity. Findings from the Framingham Study (59) showed that a modest amount of sustained weight loss reduced the risk of diabetes by 37% in 618 overweight individuals. The effect was even stronger for overweight ($\text{BMI} \geq 29 \text{ kg/m}^2$) individuals among whom sustained weight loss was associated with a 62% reduction in the risk of diabetes. Additionally, in the Health Professionals Follow-up Study (44) of 22,171 men, the risk of developing diabetes was reduced by about 50% as a result of weight loss exceeding 6 kg over a 10-yr period.

Physical Activity

A number of prospective cohort studies have indicated that physical activity is associated with a significant reduction in the risk of type 2 diabetes, whereas a sedentary lifestyle is associated with an increased risk (45,47,60–66). For instance, in the Nurses' Health Study (66), the risk of type 2 diabetes decreased with increasing amounts of total physical activity. Compared with women with the lowest level of total physical activity, those with the highest level had a 46% lower risk, independent of major risk factors for diabetes (Fig. 11). Moreover, the inverse dose-response relationship persisted after controlling for BMI (66). In the same cohort of nurses, time spent watching television, a major sedentary behavior in the United States, was significantly positively related to the risk of diabetes (61); each 2-h daily increment in watching television was associated with a 14% increase in the risk of diabetes. Similar findings were obtained from a cohort of men (the Health Professional's Follow-up Study) showing a 20% increased risk of diabetes for each 2-h daily increment in watching television (63). In addition, compared with men with the lowest level of total physical activity, those with the highest level had a 49% lower risk of diabetes (Fig. 11).

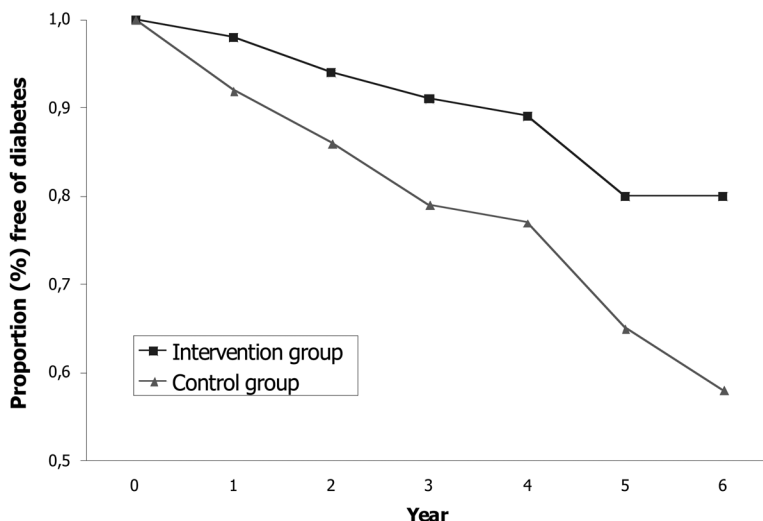


Fig. 12. Proportion of subjects remaining free of diabetes during study period in Finnish Diabetes Prevention Study. (Adapted from ref. 67.)

Lifestyle Modification and Risk of Type 2 Diabetes

Randomized controlled trials in Finland and the United States have demonstrated the feasibility and efficiency of lifestyle intervention programs in the prevention of diabetes in individuals with impaired glucose tolerance. The lifestyle intervention program in the Finnish trial (67) aimed to achieve a reduction in weight of 5% or more; moderate exercise for at least 30 min/d; an intake of total and saturated fat of <30 and <10%, respectively; and an increase in fiber intake to at least 15 g/1000 kcal. Subjects in the intervention group were also recommended to consume frequently whole-grain foods, vegetables, fruits, low-fat milk and low-fat meat products, soft margarines, and vegetable oils rich in monounsaturated fatty acids. The lifestyle program was associated with a 58% reduction in risk of developing diabetes, and the 4-yr cumulative incidence of diabetes was 11% in the intervention group in comparison with 23% in the control group (Fig. 12). The US Diabetes Prevention Project (68) aimed to achieve and maintain a weight reduction of at least 7% through a healthy low-calorie, low-fat diet and to engage in moderate physical activity for at least 150 min/wk. This trial showed that over 3-yr, the lifestyle intervention reduced the risk of progressing from impaired glucose tolerance to diabetes by 58%, whereas the oral hypoglycemic drug metformin reduced the risk by 31%; the 3-yr cumulative incidence of diabetes was 14% in the intervention group and 29% in the control group. The results of these two trials are also similar to those from the Da Qing Impaired Glucose Tolerance and Diabetes Study in China (69), showing that modification of diet and/or exercise level can significantly decrease the risk of diabetes in individuals with impaired glucose tolerance.

Summary

Besides genetic predisposition, there is ample evidence that such modifiable lifestyle factors as obesity and physical inactivity are important determinants of the development of type 2 diabetes. Furthermore, it has been demonstrated that lifestyle modifications, including changes in exercise and dietary practices, the primary factors in determining weight loss, can effectively delay or prevent the development of diabetes in high-risk groups.

CONCLUSIONS

The prevalence of obesity in adults, children, and adolescents has increased dramatically globally over the last few decades and there is no sign of it abating. About half of the adult population in the United States and other Western countries is currently estimated to be overweight or obese. Urban areas of some developing countries are approaching similar proportions.

As for obesity, the number of persons with diabetes is reaching epidemic proportions (70), and it has been projected that the prevalence will grow substantially over the next several decades (1). The increasing prevalence of type 2 diabetes is indicative of the effects of globalization and industrialization, which affects all nations, with obesity, sedentary lifestyle, and inappropriate diet the predominant factors involved.

Because obesity and diabetes are major causes of morbidity and mortality, reversing the obesity and diabetes epidemics is of utmost importance. The trend of increasing prevalence of obesity and diabetes all over the world has already imposed an enormous burden on health-care systems, and this will continue to increase in the future. Thus, prevention of these two diseases in adults, and especially in children and adolescents, should be an essential component of future public health intervention programs.

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