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REVIEW

Global Trend in Overweight and Obesity and Its Association With Cardiovascular Disease Incidence

Hiroshi Yatsuya, MD, PhD; Yuanying Li, PhD; Esayas Haregot Hilawe, PhD; Atsuhiko Ota, MD, PhD; Chaochen Wang, BSc; Chifa Chiang, PhD; Yan Zhang, BSc; Mayu Uemura, BSc; Ayaka Osako, BSc; Yukio Ozaki, MD, PhD; Atsuko Aoyama, MD, PhD

Although the global prevalence of both the overweight and obese is on the rise, there are variations among regions or countries, and sexes. Approximately half or more than half of the population are overweight/obese defined as body mass index ≥25 kg/m² in the Americas (61.1%), Europe (54.8%), and Eastern Mediterranean (46.0%) according to the World Health Organization, while a much lower prevalence is observed in Africa (26.9%), South-East Asia (13.7%), and the Western Pacific (25.4%). Females are more likely to be overweight/obese in the Eastern Mediterranean, Africa, South-East Asia and the majority of countries in the Americas and Western Pacific but not in the most of the countries in Europe. These region-sex-ethnicity differences in prevalence may be a clue to the causes of the obesity epidemic. Epidemiological studies done in the USA, Europe, and Asia found that higher BMI was significantly associated with increased incidence of coronary artery disease (CAD) and ischemic stroke, but the association with hemorrhagic stroke incidence was not always consistent. The association of BMI with CAD and ischemic stroke was generally independent of known mediators, which would indicate the importance of controlling or preventing overweight/obesity for the prevention of cardiovascular disease. (*Circ J* 2014; **78:** 2807–2818)

Key Words: Coronary artery disease; Epidemiology; Ischemic stroke; Obesity; Stroke

Obesity is a state of excess fat accumulation that accompanies wide range of health disadvantages. The World Health Organization (WHO) defines a body mass index (BMI) of ≥25 kg/m² as overweight, and a BMI of ≥30 kg/m² as obesity.[1] The global prevalence of the overweight and obese is on the rise.[2] The Global Burden of Disease Study estimated that the proportion of overweight or obese adults in 2013 was 36% in men and 37% in women worldwide.[3] Globally, the epidemic has affected both developed and developing countries, men and women, and adults and children, although there are great variations in their prevalence and trends among regions or countries, and sexes.

Because obesity is believed to cause a number of established risk factors for cardiovascular diseases (CVD) such as hypertension, dyslipidemia, and diabetes,[4] the growing prevalence of obesity is assumed to increase the global CVD burden. However, it is also known that other changes in diet and lifestyle have led to changes in the prevalence of these risk factors, and presumably in CVD incidence.[5,6] An example of this would be a dramatic decrease in stroke mortality observed after World War 2 in Japan because of the decrease in severe hypertension,[7] although the average BMI also increased during this period.[8–10] Therefore, the association of obesity with CVD remains to be investigated, especially in terms of differences in the association by time period as well as how the association (if any) would be mediated by the established risk factors.[11] Also, there may be differences in the threshold of BMI where significant BMI would be observed, because significant differences exist in the prevalence of obesity by sex and ethnicity. Hence, we set 2 aims in this review. The first aim was to provide an overview of global trends of overweight and obesity according to the WHO regions and countries within each region by sex. The second aim was to provide up-to-date information on cohort studies that have investigated the associations of BMI with coronary artery disease (CAD) and stroke in various parts of the world.

Methods

Overweight and Obesity Trends

The review compiles the prevalence of overweight and obesity for every country in the WHO's 6 regions of the world (Africa, the Americas, Eastern Mediterranean, South-East Asia, Western Pacific, and Europe).

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Department of Public Health (H.Y., Y.L., A. Ota), Department of Cardiology (H.Y., Y.O.), Fujita Health University School of Medicine, Toyoake; Department of Public Health and Health Systems, Nagoya University Graduate School of Medicine, Nagoya (H.Y., E.H.H., C.W., C.C., Y.Z., M.U., A. Osako, A.A.), Japan; and Department of Public Health, School of Medicine, Mekelle University, Mekelle (E.H.H.), Ethiopia

Mailing address: Hiroshi Yatsuya, MD, PhD, Department of Public Health, Fujita Health University School of Medicine, 1-98 Dengakugakubo, Kutsukake-cho, Toyoake 470-1192, Japan. E-mail: yatsuya@fujita-hu.ac.jp

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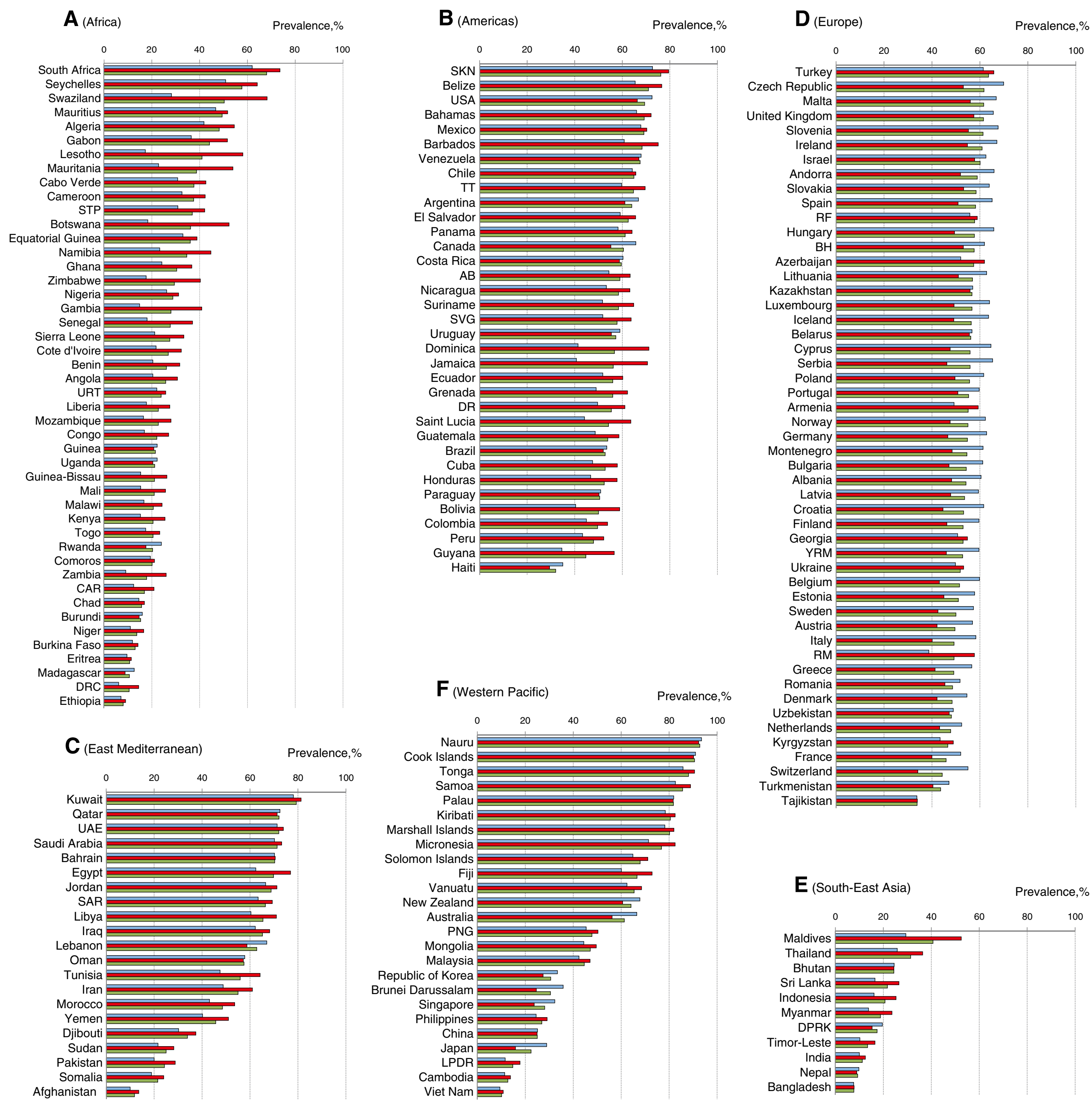

Figure 1. Bar graphs showing the prevalence of overweight/obesity (BMI ≥25 kg/m²) among adults aged ≥20 years in countries of the 6 WHO regions of the world in 2008. (**A**–**F**) Estimates for every country in Africa, the Americas, East-Mediterranean, Europe, South-East Asia, and the West Pacific, respectively, for which data were available. Blue, men; red, women; green, total. Countries are sorted according to the prevalence of overweight in total population. All estimates are age standardized. BMI, body mass index; CAR, Central African Republic; DRC, Democratic Republic of the Congo; STP, Sao Tome and Principe; URT, United Republic of Tanzania (**A**), AB, Antigua and Barbuda; DR, Dominican Republic; SKN, Saint Kitts and Nevis; SVG, Saint Vincent and the Grenadines; TT, Trinidad and Tobago; USA, United States of America (**B**), Iran, Islamic Republic of Iran; SAR, Syrian Arab Republic; UAE, United Arab Emirates (**C**), BH, Bosnia and Herzegovina; RM, Republic of Moldova; RF, Russian Federation; YRM, The former Yugoslav Republic of Macedonia (**D**), DPRK, Democratic People's Republic of Korea (**E**), Micronesia, Federated States of Micronesia; LPDR, Lao People's Democratic Republic; PNG, Papua New Guinea (**F**). Coefficients of variation (CV) of the prevalence of overweight/obesity were 0.47 in Africa, 0.15 in the Americas, 0.37 in the East-Mediterranean, 0.10 in Europe, 0.50 in South-East Asia, and 0.51 in West Pacific. Data were obtained from the WHO Global Health Observatory Data Repository and reproduced with permission, http://apps.who.int/gho/data/node.main.A896?lang=en.

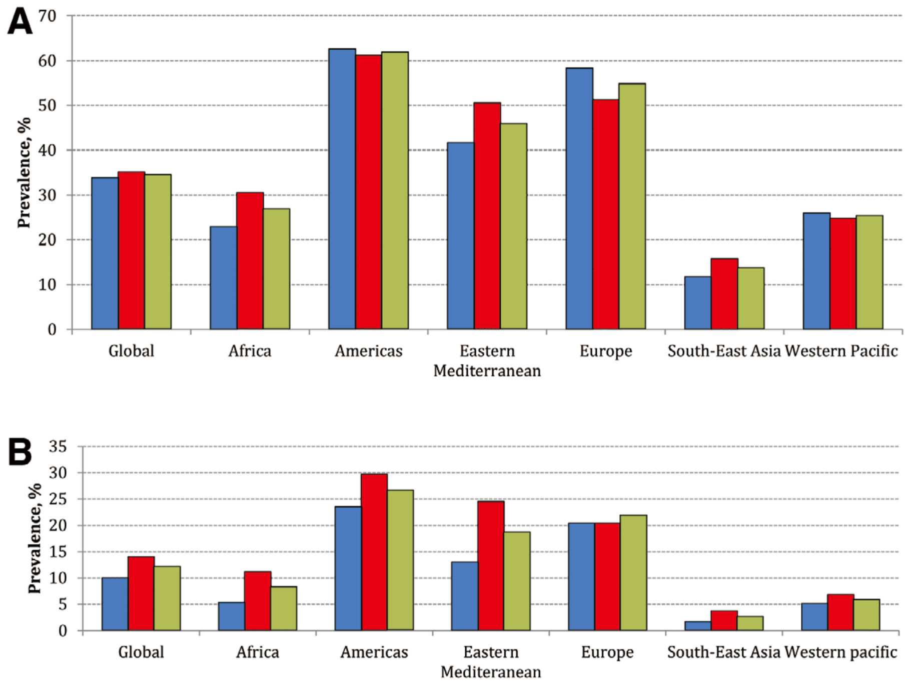

Figure 2. Bar graphs showing the prevalence of overweight/obesity (BMI ≥25 kg/m², **A**) and obesity (BMI ≥30 kg/m², **B**) among adults aged ≥20 years in the 6 WHO regions of the world in 2008. Blue, men; red, women; green, total. All estimates are age standardized. BMI, body mass index. Data were obtained from the WHO Global Health Observatory Data Repository and reproduced with the permission, http://apps.who.int/gho/data/node.main.A896?lang=en.

The data were primarily obtained from the WHO's Global Health Observatory Data Repository (http://apps.who.int/gho/data/node.main.A896?lang=en) in July 2014. The most recent data available (2008) were used for the analyses. Age-standardized estimates were used in preference to crude estimates so that comparison among countries and among regions would be possible. Comparisons among regions and countries have been described and reproduced here with permission from the WHO. We elaborated country-level comparisons in each region. As shown in **Figures 1** and **S1**, countries were sorted according to prevalence in the total population. As a measure of heterogeneity within a region, the coefficient of variation (CV) of the prevalence of overweight/obesity was calculated. The 10-year trend (2000–2009) of the mean BMI in 24 selected countries (4 from each region) was also examined. The 24 countries were purposefully selected by the authors, because they are the main countries with big population in each region.

Review of Prospective Studies

We searched for relevant literature in PubMed using keywords: cohort study, follow up study, body weights and measures, body mass index, coronary heart/artery disease, ischemic heart disease, stroke. We restricted our search to studies of incidence because mortality would be affected by a number of other factors. As the present review was not systematic, the search was also restricted to studies published within 5 years as of June 2014. However, older literature was selected from previous reviews, meta-analyses, or consortia. CAD was defined in the studies included in the review as fatal or non-fatal myocardial infarction and sudden death within 1 h of onset of symptoms. Angina associated with cardiac procedures was not usually included as it can be influenced by the healthcare setting. Stroke was classified as ischemic or hemorrhagic. When possible, the latter was further restricted to intracerebral hemorrhage.

The following information was obtained: mean age or the range, mean BMI or the range, sample size, BMI of the reference category, lowest BMI significantly associated with the incidence, and list of confounding and mediating variables included in the statistical model. Relevant information was extracted separately for sex whenever possible.

Results

Prevalence of Overweight/Obesity

According to the estimates of the WHO, more than one-third (34.5%) of adults in the world aged ≥20 years were overweight or obese in 2008, with females (35.1%) having a slightly higher preponderance than males (33.8%). However, these figures are highly variable when separately analyzed for the 6 WHO-designated regions; the Americas, Europe, and Eastern Mediterranean regions had the highest proportion of overweight/obese adults at 61.1%, 54.8% and 46.0%, respectively. Unlike observations in the rest of the world, males in Europe were more likely to be overweight/obese than their female counterparts (**Figure 2A**). This also applies to some relatively high income countries in the Americas and Western Pacific region (described later).

Separate analyses for obesity show that approximately 12%

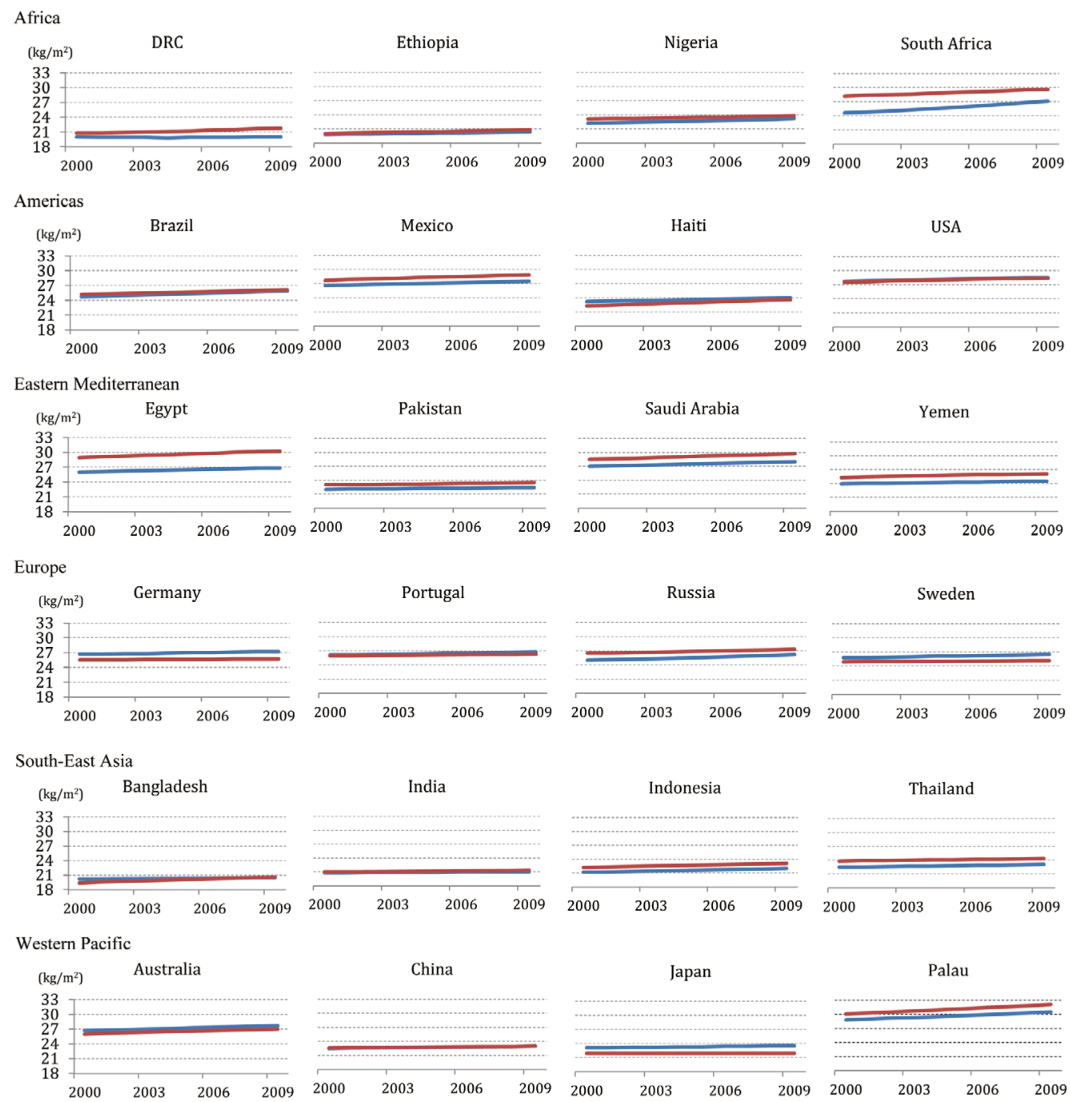

Figure 3. Ten-year (2000–2009) trend of mean BMI in 24 selected countries representing the 6 WHO regions of the world: Africa (represented by Democratic Republic of Congo (DRC), Ethiopia, Nigeria and South Africa); the Americas (represented by Brazil, Haiti, Mexico, and the United States of America (USA)); East-Mediterranean (represented by Egypt, Pakistan, Saudi Arabia and Yemen); Europe (represented by Germany, Portugal, Russia, and Sweden); South-East Asia (represented by Bangladesh, India, Indonesia, and Thailand); and the West Pacific (represented by Australia, China, Japan, and Palau). All estimates are age standardized. Blue, males; red, females. BMI, body mass index. Data obtained from the WHO Global Health Observatory Data Repository and reproduced with the permission, http://apps.who.int/gho/data/node.main.A896?lang=en.

of the global adult population was obese in 2008. The Americas (26.7%), Europe (21.9%), and the Eastern Mediterranean (18.7%) were the top 3 regions with the highest burden of the disease (Figure 2B).

Overweight/Obesity in Africa

Overall, 26.9% of African adults were overweight or obese in 2008, with notable heterogeneity among countries (CV: 0.47). South Africa (68.0%), the Seychelles (57.7%) and Swaziland (50.3%) topped the list of African countries with the highest prevalence of overweight or obesity among adults (Figure 1A). The same 3 countries had the highest proportion of adults with obesity: South Africa (33.5%), the Seychelles (24.6%) and Swaziland (23.4%) (Figure S1A). Ethiopia (8.0%), Eritrea (10.7%) and Burkina Faso (13.0%) made the last 3 with regard to prevalence of overweight or obesity, and Ethiopia, Madagascar, and Eritrea had the lowest prevalence of obesity in the region at 1.2%, 1.7%, and 1.8%, respectively.

Generally, obesity was twice more common among females than it was among males in Africa.

Overweight/Obesity in the Americas

The proportion of overweight and obese adults is the highest in the Americas among the 6 WHO regions (Figures 1A,B). The prevalence of overweight/obesity and obesity was 61.9% and 26.7% in that order. In almost all countries in the region, more than half of the population was overweight or obese. Saint Kitts and Nevis (76.2%), Belize (71.0%) and the United States of America (69.4%) were the top 3 countries with the highest proportions of overweight/obese adults in the region, while Haiti (32.0%), Guyana (44.7%) and Peru (47.9%) relatively had the lowest prevalence of the condition (Figure 1B).

The overall prevalence of overweight/obesity was slightly higher in males (62.6%) than in females (61.2%), but obesity was more common in females (29.7%) than it was in males (23.5%) (Figures 2A,B).

Overweight/Obesity in the Eastern Mediterranean

The Eastern Mediterranean region is home to most of the oil-rich Arab countries. Although the overall prevalence of overweight/obesity was 46.0%, country-specific figures were 55% or above in the majority of the countries, with modest heterogeneity (CV: 0.37). Gulf countries such as Kuwait (79.3%), Qatar (72.1%) and the United Arab Emirates (72.0%) had the highest proportion of overweight/obese adults in the region, while poverty-stricken countries such as Afghanistan (11.8%), Somalia (21.5%), and Pakistan (24.3%) had relatively the lowest proportion of overweight/obese people (Figure 1C).

Approximately 18.7% of adults in the region were obese. Kuwait (42.8%), Saudi Arabia (35.2%), and Egypt (34.6%) were the top 3 in the list of countries with high proportions of obese adults (Figure S1C). Afghanistan (11.8%), Somalia (21.5%), and Pakistan (24.3%) made the bottom end of the list.

Females were more likely to be overweight and obese than their male counterparts in all countries in the region.

Overweight/Obesity in Europe

The proportion of overweight/obese adults is the second largest in Europe (54.8%) in the world (Figures 2A,B). Most countries in the region had a similar prevalence of overweight/obesity (CV: 0.10); Turkey, Czech Republic and Malta had relatively the highest share at 63.8%, 61.7%, and 61.6%, respectively, whereas Tajikistan (33.8%), Turkmenistan (43.8%) and Switzerland (44.3%) had relatively the smallest number of overweight/obese adults (Figure 1D).

More than one-fifth (21.9%) of the regions' adults were obese in 2008. The prevalence of obesity was similar across countries in the region. The same group of countries with the highest and lowest proportions of overweight people also had the highest and lowest proportion of obese people in the region (Figure S1D).

There were some peculiarities with regard to the sex distribution of overweight and obesity in the region. Overweight/obesity was more common among males than among females in most countries, but the likelihood of obesity was similar for both sexes.

Overweight/Obesity in South-East Asia

The prevalence of overweight/obesity (13.3%) and obesity (2.7%) in South-East Asia was the lowest in 2008 (Figures 2A,B) among the 6 WHO regions. However, there were notable differences across countries (CV: 0.50). The Maldives, Thailand and Bhutan had the highest proportion of both overweight/obese and obese adults in the region (Figures 1E,S1E). The prevalence of overweight/obesity in the 3 countries were 40.7%, 31.7% and 24.4%, while corresponding figures for obesity were 16.7%, 8.5% and 5.5%, respectively. In contrast, Bangladesh, Nepal, and India had the lowest proportion of adults with overweight/obesity and obesity: the prevalence of overweight/obesity was 7.7%, 9.3%, and 11.2%, whereas that of obesity was 1.1%, 1.5%, and 1.9%, in that order.

In most countries of the region, females were more likely to be overweight/obese and obese than their male counterparts.

Overweight/Obesity in the Western Pacific

The overall prevalences of overweight/obesity and obesity in the Western Pacific were 25.4% and 21.9%, respectively. However, country-specific figures showed wide variation (CV: 0.51). The prevalence of overweight/obesity exceeded 60% in most of the island countries. Nauru, Cook Islands and Tonga had 92.8%, 90.6% and 88.1% overweight/obese adults, in that order (Figure 1F). These countries also had the highest proportion of obese adults in the region at 71.1%, 64.1% and 59.5%, respectively (Figure S1F). In contrast, the prevalence of overweight/obesity in Vietnam (10.1%), Cambodia (12.7%), and Lao People's Democratic Republic (14.8%) was the lowest in the region (Figure 1F). The same 3 countries had the lowest proportion of obese adults in the region: the prevalence of obesity was 1.6%, 2.3%, and 3.0% in Vietnam, Cambodia and Lao PDR, respectively (Figure S1F).

Approximately 22.4% of adults in Japan were overweight/obese in 2008, but the proportion of obese adults was 4.5%. These figures are low in comparison to the corresponding values for Australia or New Zealand, other high-income countries in the region, but comparable to Singapore or Republic of Korea. In contrast, Japanese women had lower prevalence of overweight than women of these developed countries in the region.

Overall, overweight/obesity was more common in males than it was in females and obesity was more common in females than in males.

Trend of Mean BMI (2000–2009)

The 10-year trend of age-standardized mean BMI for 24 selected countries from each WHO region is presented (Figure 3). Generally, mean BMI steadily increased between the years 2000 and 2009 in almost all countries. In most low- and middle-income countries, females tend to have higher mean BMI than males, and the reverse was observed in high-income countries. Japanese women did not seem to experience any increase in the average level of BMI.

Summary of Prospective Studies

CAD In general, BMI was positively associated with CAD incidence independent of confounding factors such as age, smoking, alcohol drinking, and physical activity (Table 1).[12–29] The lowest BMI associated with increased risk varied by studies, in part because of different reference categories defined. Studies from the USA,[12,13] Europe,[14] Japan,[15] and other countries[16,17] showed this value to be lower than 25 in men. However, there are studies that reported the value to be 25 or greater: from the USA[18] and Europe,[19–22] and Japan.[23,24] In women, the threshold value seems to be 25 or greater according to the reports from the USA[12,13,25] and Europe,[19,20,26] except for 1 study from the USA that reported 23.[27] Furthermore, a few studies reported BMI of 30 or more: from the USA,[28] Europe (women),[19] and Japan.[24]

The association of BMI with the incidence CAD remained significant after inclusion of mediators such as total cholesterol, systolic blood pressure (SBP) and diabetes in the statistical model in many studies, including the Framingham Heart Study,[12] JALS,[15] and the Korea Medical Insurance Corporation study.[17]

Ischemic Stroke (Table 2) BMI was positively associated with ischemic stroke incidence independent of confounding

Table 1. Cohort Studies Reporting an Association of BMI With the Incidence of CAD

Country, study name‡	Year of publication	Baseline, year	Follow-up, years	Age, range or mean, years	BMI, mean, kg/m²	Sample size	Sex
USA, Framingham Heart Study[12]	2000	1956	Max. 24.0	30–62	NA	2,213	M
						2,567	W
USA, Nurses' Health Study[27]	2006	1980	Max. 20.0	34–59	NA	88,393	W
USA, Health Professionals Follow-up Study[13]	2010	1986	Max. 16.0	39–75	25.5	27,859	M
USA, Nurses' Health Study		1986	Max. 16.0	39–65	25.3	41,534	W
USA, ARIC Study[28]	1998	1987–1989	Mean 6.2	45–64	27.4†	6,618	M
					27.7†	7,852	W
USA, Physicians' Health Study[18]	2001	1988	Mean 3.9	40–84	25.4	16,164	M
USA, Women's Health Study[25]	2008	1992	Mean 10.9	≥45	26.0	38,987	W
UK, Renfrew-Paisley Study[19]	2006	1972–1976	Max. 20.0	45–64	25.9†	6,992	M
					25.9†	8,152	W
UK, British Regional Heart Study[14]	1997	1978–1980	Mean 14.8	40–59	25.5	7,735	M
Northern Ireland and France, PRIME Cohort Study[29]	2010	1991–1993	Max. 10.0	50–59	25.5	10,602	M
UK, EPIC-Norfolk Study[21]	2007	1993–1997	Mean 9.1	45–79	26.6	11,117	M
					26.3	13,391	W
UK, Scottish Health Cohort Study[20]	2013	1995/1998, 2003	Median 10.0	44.6	NA	9,320	M
				45.1		12,161	W
UK, Million Women Study[26]	2013	1996–2001	Mean 9.0	56.0	26.1	1,178,939	W
Denmark, Copenhagen General Population Study[22]	2014	2003–2011	Median 3.6	20–100	NA	31,294	M(–)#
							M(+)#
						40,233	W(–)#
							W(+)#
Australian, Sax Institute's 45 and UP Study[16]	2014	2006–2008	Median 3.4	45–103	NA	158,546	Combined
Japan, CIRCS[23]	2007	1975–1987, varies by communities	Median 18.3	40–69	22.9†	3,595	M
					23.4†	5,492	W
Japan, JALS[15]	2010	1985–1999, varies by cohorts	Max. 20.0	40–89	23.0	19,760	M
					23.4	25,475	W
Japan, JPHC Study[24]	2008	1990–1993	Mean 9.7	40–69	NA	43,235	M
						47,444	W
Korea, Korea Medical Insurance Corporation Study[17]	2005	1990–1992	Max. 9.0	35–59	23.0†	133,740	Combined

†Calculated by authors, *Result from MI, #(–) denotes without metabolic syndrome, (+) with metabolic syndrome. ‡ARIC, Atherosclerosis Risk in Communities Study; CIRCS, Circulatory Risk in Communities Study; EPIC-Norfolk, European Prospective Investigation Into Cancer and Nutrition in Norfolk Cohort; JALS, Japan Arteriosclerosis Longitudinal Study; JPHC Study, Japan Public Health Center-Based Study. BMI, body mass index; CAD, coronary artery disease; CHD, coronary heart disease; DM, diabetes; FEV1, forced expiratory volume in 1 second; HC, high cholesterol or dyslipidemia or hypercholesterolemia; HDLC, high-density lipoprotein cholesterol; HTN, hypertension; HRT, hormone replacement therapy; LDLC, low-density lipoprotein cholesterol; NA, not available; M, men; W, women; MI, myocardial infarction; Ref, reference category; RTA, randomized treatment assignments; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride. Variables: dr, drinking; edu, education; ex, physical activity or exercise; fhx, family or parental history; hx, history; meno, menopausal status; salary, income or salary; sm, smoking.

(Table 1 continued the next page.)

Country, study name‡	Model with confounding variables			Model with mediator variables	
	Ref	Lowest BMI with association	Variables adjusted	Lowest BMI with association	Variables adjusted
USA, Framingham Heart Study[12]	<23.8 <22.3	23.8 27.6	Age, sm	23.8 27.6	Plus TC
USA, Nurses' Health Study[27]	18.5–22.9	23.0	Age, sm, dr, fhx of CHD, meno, HRT, aspirin use		
USA, Health Professionals Follow-up Study[13] USA, Nurses' Health Study	18.5–22.9	23.0 25.0	Age	23.0 25.0	Plus sm, dr, fhx of MI, height, marital status, profession, HRT, saturated fat, trans fat, polyunsaturated fats, folate, vitamin E, total energy, HC, HTN, DM
USA, ARIC Study[28]	<24.7 <23.3	None 31.0	Age, sm, dr, ethnicity, fhx of CHD		
USA, Physicians' Health Study[18]	<22.8	25.7 25.7*	Age, sm, dr, ex, RTA, fhx of MI, multivitamins, aspirin use		
USA, Women's Health Study[25]	<25.0	25.0	Age, sm, dr, RTA, parental hx of MI, HRT, dietary factors		
UK, Renfrew-Paisley Study[19]	18.5–24.9	25.0, 25.0* 30.0, 30.0*	Age, sm, adjusted FEV1, social class		
UK, British Regional Heart Study[14]	20.0–21.9	24.0	Age, sm, dr, ex, social class		
Northern Ireland and France, PRIME Cohort Study[29]	First quintile	Third quintile	Age, center	None	Plus sm, dr, ex, edu, HTN, DM, HDLC, TG
UK, EPIC-Norfolk Study[21]	<23.9 <22.8	25.5 24.7	Age	27.0 24.7	Plus sm, dr, ex, SBP, TC
UK, Scottish Health Cohort Study[20]	18.5–24.9	25.0 25.0	Age, sm, dr, year of survey		
UK, Million Women Study[26]	22.5–24.9	25.0	Age, sm, dr, ex, social class		
Denmark, Copenhagen General Population Study[22]	18.5–24.9			30.0, 30.0* 25.0, 25.0* None, 25.0* 25.0, 25.0*	Age, sm, plasma LDLC, lipid-lowering medication use, aspirin use
Australian, Sax Institute's 45 and UP Study[16]	20.0–22.49	22.5	Age, sex, sm, dr, edu, region of residence, salary, health insurance		
Japan, CIRCS[23]	<25.0	25.0 None	Age, community	None None	Plus sm, dr, meno, time since last meal, serum TC
Japan, JALS[15]	<21.0	23.0* None*	Age, sm, dr	27.5* None*	Plus SBP, serum TC
Japan, JPHC Study[24]	23.0–24.9	30.0, 27.0* None, None*	Age	30.0, 30.0* None, None*	Plus sm, dr, ex, hx of HTN, DM, public health center, intake of green vegetables, fish
Korea, Korea Medical Insurance Corporation Study[17]	18.0–19.0	23.0 25.0*	Age, sex, sm, dr, ex, health insurance	23.0 30.0*	Plus HTN, DM, TC

factors in studies across the USA,[30–32] Europe[33–35] and Asia.[15,36–41] A few studies found the association only in men[42,43] or in women[16,44] in contrast to CAD, adjusting for mediators such as SBP and diabetes significantly attenuated the association in most studies from the USA[30,32,33] and Europe.[34] However, some studies in East Asia[36,39–41,43,44] and Finland[35] indicated the associations to be independent of such mediators.

Hemorrhagic Stroke (Table 3) Relatively few studies have been performed in the USA and Europe probably because hemorrhagic stroke is less prevalent. BMI values that showed a significant association with increased incidence of hemorrhagic stroke are in the range 25–30 kg/m^2 in studies in Asia[15,37–39,41,43,44] and the USA.[31] After adjusting for mediators, namely SBP or hypertension, the association became attenuated in most studies.[15,40,43] However, there is a study that showed increased hemorrhagic stroke risk in women with

Table 2. Cohort Studies Reporting an Association of BMI With the Incidence of Ischemic Stroke

Country, study name‡	Year of publication	Baseline, year	Follow-up, years	Age, range or Mean, years	BMI, mean, kg/m^2	Sample size	Sex
USA, Nurses' Health Study[30]	1997	1980	Max. 12.0	34–59	NA	93,337	W
USA, Physicians' Health Study[31]	2002	1982	Mean 12.5	53.1#	24.9	21,414	M
USA, ARIC Study[32]	2010	1987/1989	Median 16.9	45–65	27.6	7,619	Black M
					27.4	4,566	White M
					30.8	2,330	Black W
					26.6	5,289	White W
USA, Women's Health Study[33]	2005	1993	Mean 10.0	≥45	26.0	39,053	W
Sweden, Multifactor Primary Prevention Study[34]	2004	1970	Max. 28.0	47–55	25.5	7,402	M
Sweden, Swedish Women's Life-style and Health Cohort Study[42]	2006	1991–1992	Mean 11.4	30–50	NA	45,449	W
Finland, Six Independent Cross-sectional Population Surveys[35]	2007	1972–1997, varies by cohorts	Mean 19.5	25–74	NA	23,967	M
						26,029	W
Japan, CIRCS[16]	2007	1975–1987, varies by community	Median 18.3	40–69	22.9†	3,813	M
					23.4†	5,646	W
Japan, JALS[15]	2010	1985–1999, varies by cohort	Max. 20.0	40–89	23.0	19,760	M
					23.4	25,475	W
Japan, Hisayama Study[43]	2011	1988	Max. 12.0	40–79	NA	1,037	M
						1,384	W
Japan, JPHC Study[44]	2011	1995–1998/1999	Median 7.9	45–74	NA	32,847	M
						38,875	W
China, China Stroke Prevention Project[36]	2013	1987	Max. 11.0	>35	NA	12,560	M
						14,047	W
China, China National Hyperten-sion Survey[37]	2010	1991	Mean 8.3	≥40	22.6	75,655	M
						79,081	W
China, Shanghai Women's Health Study[38]	2009	1996–2000	Mean 7.3	40–70	23.9	67,083	W
China, Kailuan Study[39]	2013	2006–2007	Mean 4.0	18–98	25.0	94,744	Combined
Korea, no study name[40]	2004	1986–1990	Max. 10.0	40–64	23.1	234,863	M
Korea, Korean Prevention Cancer Study[41]	2008	1992–1995	Max. 13.0	30–95	23.2	439,582	W#

†Calculated by authors, #nonsmoker. ‡ARIC, Atherosclerosis Risk in Communities Study; CIRCS, Circulatory Risk in Communities Study; JALS, Japan Arteriosclerosis Longitudinal Study; JPHC Study, Japan Public Health Center-Based Study. BG, blood glucose; BP, blood pressure; FBG, fasting BG; OC, oral contraceptive use. Other abbreviations as in Table 1.

(Table 2 continued the next page.)

BMI ≥30 kg/m^2 independent of hypertension and diabetes.[44]

Discussion

We confirmed a global obesity trend that is on the rise, although there are significant variations by sex, regions of the world and countries. Cultural perceptions towards obesity may serve as a possible explanation for the observed sex differences in the distribution. For instance, obesity is seen as a sign of wealth and an important attribute of beauty for women in Africa.[45] Women traditionally are expected to stay at home in most of the countries in the Eastern Mediterranean region, and this may have contributed to the observed sex disparity in the prevalence of obesity in the region. East Asian women generally had lower BMI than men and women in other regions, which may be related to social norms (pressure).[46–48] These region-sex-ethnicity differences in prevalence may be a clue to the causes of the obesity epidemic. More studies, including qualitative ones that collect individual risk factors and behaviors, are warranted. One of the limitations of comparisons across countries by using international reports such as the one we used (ie, WHO Global Health Observatory Data Repository) would be differences in the survey methods, and data for some countries are estimates modeled using data from other

Country, study name‡	Model with confounding variables			Model with mediator variables	
	Ref	Lowest BMI with association	Variables adjusted	Lowest BMI with association	Variables adjusted
USA, Nurses' Health Study[30]	<21.0	29.0	Age, sm, dr, ex, OC, meno, HRT, time period, aspirin use, antioxidant score	None	Plus HTN, DM, HC
USA, Physicians' Health Study[31]	<23.0	25.0	Age, sm, dr, ex, hx of angina, fhx of MI prior to 60 years of age, RTA		
USA, ARIC Study[32]	14.4–<23.9	32.0	Age, sm, dr, ex, edu	None	Plus SBP, HTN medication, DM, HDLC, von Willebrand factor, albumin
		32.0		None	
		None		None	
		32.0		None	
USA, Women's Health Study[33]	<20.0	27.0	Age, sm, dr, ex, HRT	None	Plus hx of HTN, DM, HC
Sweden, Multifactor Primary Prevention Study[34]	20.0–22.49	30.0	Age, sm, ex, fhx of stroke, occupational class, stress	None	Plus SBP, HTN treatment, DM, serum TC
Sweden, Swedish Women's Lifestyle and Health Cohort Study[42]	20.0–24.9	None	Age, sm, dr, edu, age at first birth, use of OC	None	Plus hx of HTN, DM
Finland, Six Independent Cross-sectional Population Surveys[35]	18.5–24.9	25.0	Age, sm, dr, ex, edu, study year, fhx of stroke	25.0	Plus SBP, TC, hx of DM
		30.0		30.0	
Japan, CIRCS[16]	<25.0	None	Age, community	None	Plus sm, dr, time since last meal, meno, serum TC
		25.0		None	
Japan, JALS[15]	23.0–24.9	27.5	Age, sm, dr	None	Plus SBP, TC
		25.0		None	
Japan, Hisayama Study[43]	<21.0	25.0	Age	23.0	Plus sm, dr, ex, SBP, ECG abnormalities, DM, TC, HDLC, TG
		None		None	
Japan, JPHC Study[44]	23.0–24.9	None	Age, study community	None	Plus sm, dr, HTN, DM
		27.0		30.0	
China, China Stroke Prevention Project[36]	18.5–24.9	25.0	Age, sm, dr, edu	25.0	Plus hx of DM, HTN, heart disease
		25.0		25.0	
China, China National Hypertension Survey[37]	18.5–24.9	25.0	Age, sex, sm, dr, ex, edu, residence area		
		25.0			
China, Shanghai Women's Health Study[38]	<21.1	24.4	Age, sm, dr, ex, edu, occupation, salary, meno, use of OC, HRT, aspirin, intake of saturated fat, vegetables, fruits, sodium		
China, Kailuan Study[39]	<22.05	22.05	Age, sex, sm, dr, ex, edu, salary, marital status	24.0	Plus hx of HTN, DM, HC
Korea, no study name[40]	22.0–23.9	24.0	Age, sm, dr, ex, salary	24.0	Plus BP, BG, TC
Korea, Korean Prevention Cancer Study[41]	18.5–19.9	20.0	Age, dr, ex	23.0	Plus FBG, SBP, TC

countries and specific country characteristics.[2]

We also found that higher BMI was significantly associated with increased incidence of CAD and ischemic stroke and to a lesser degree with the incidence of hemorrhagic stroke among relatively recent studies included in the review. However, these findings are somewhat inconsistent with old (baseline years being 1960 s to 1970 s) studies carried out in Japanese[49,50] or in African Americans.[51,52] This might be related to the fact that hypertension without being overweight used to constitute most of the cases of hypertension in rural communities in Japan in the 1960 s, but it decreased significantly by the 1980s, accompanied by increases in the proportion of hypertension among the overweight.[53]

BMI cutoff value differed by studies, which precluded definite statement about the threshold. However, BMI ≥25.0 kg/m² would be a reasonable representation of increased CVD risk, although there may be lower cutoff for BMI than 25.0 (ie, 23.0), implying that the association of BMI with CVD may be linear. Future studies may provide a more accurate view regarding the threshold by using the same reference and BMI cutoff values.

Variables included in the statistical models varied among studies as well. Models with similar or same variables would be informative when comparing the results to infer differences by ethnicity, sex or other traits of the studied population. Another limitation of the present review is that we only collected studies on BMI. Studies using other obesity measures may have yielded different results.[54] Also, this was not a systematic review. Information provided here may not be thorough. However, we believe that obesity, however it is measured, significantly increases the risk of CAD and ischemic stroke and probably hemorrhagic stroke.

Table 3. Cohort Studies Reporting an Association of BMI With the Incidence of Hemorrhagic Stroke

Country, study name‡	Year of publication	Baseline, year	Follow-up, years	Age, range or mean, years	BMI, mean, kg/m^2	Sample size	Sex
USA, Nurses' Health Study[30]	1997	1980	Max. 12.0	34–59	NA	93,337	W
USA, Physicians' Health Study[31]	2002	1982	Mean 12.5	53.1[#]	24.9	21,414	M
USA, Women's Health Study[33]	2005	1993	Mean 10.0	≥45	26.0	39,053	W
Sweden, Multifactor Primary Prevention Study[34]	2004	1970	Max. 28.0	47–55	25.5	7,402	M
Sweden, Swedish Women's Life-style and Health Cohort Study[42]	2006	1991–1992	Mean 11.4	30–50	NA	45,449	W
Finland, Six Independent Cross-sectional Population Surveys[35]	2007	1972–1997, varies by cohort	Mean 19.5	25–74	NA	23,967 26,029	M W
Japan, JALS[15]	2010	1985–1999, varies by cohort	Max. 20.0	40–89	23.0 23.4	19,760 25,475	M W
Japan, Hisayama Study[43]	2011	1988	Max. 12.0	40–79	NA	1,037 1,384	M W
Japan, JPHC Study[44]	2011	1995/1998–1999	Median 7.9	45–74	NA	32,847 38,875	M W
China, China Stroke Prevention Project[36]	2013	1987	Mean 9.1	>35	NA	12,560 14,047	M W
China, China National Hyperten-sion Survey[37]	2010	1991	Mean 8.3	≥40	22.6	75,655 79,081	M W
China, Shanghai Women's Health Study[38]	2009	1996–2000	Mean 7.3	40–70	23.9	67,083	W
China, Kailuan Study[39]	2013	2006–2007	Mean 4.0	18–98	25.0	94,744	Combined
Korea, no study name[40]	2004	1986–1990	Max. 10.0	40–64	23.1	234,863	M
Korea, Korean Prevention Cancer Study[41]	2008	1992–1995	Max. 13.0	30–95	23.2	439,582	W[#]

†Calculated by authors, *Result from intracerebral hemorrhage; #nonsmoker. ‡CIRCS, Circulatory Risk in Communities Study; JALS, Japan Arteriosclerosis Longitudinal Study; JPHC Study, Japan Public Health Center-Based Study. Abbreviations as in Tables 1,2.

(Table 3 continued the next page.)

From the viewpoints of public health and preventive medicine, the association of BMI with CAD and ischemic stroke independent of known mediators indicates the importance of controlling or preventing overweight/obesity, because it would benefit us through unknown pathways. Recent trends in rising BMI would likely offset advancing medical and behavioral management of established risk factors, especially hypertension. Because many people still live where medical management is not so available, the global burden of obesity, and moreover, the double burden of communicable and non-communicable diseases, will likely increase if this trend continues.

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Country, study name‡	Model with confounding variables			Model with mediator variables	
	Ref	Lowest BMI with association	Variables adjusted	Lowest BMI with association	Variables adjusted
USA, Nurses' Health Study[30]	<21.0	None	Age, sm, dr, ex, OC, meno, HRT, time period, aspirin use, antioxidant score	None	Plus HTN, DM, HC
USA, Physicians' Health Study[31]	<23.0	30.0	Age, sm, dr, ex, hx of angina, fhx of MI prior to 60 years of age, RTA		
USA, Women's Health Study[33]	<20.0	None	Age, sm, dr, ex, HRT	None	Plus hx of HTN, DM, HC
Sweden, Multifactor Primary Prevention Study[34]	20.0–22.49	None*	Age, sm, ex, fhx of stroke, occupational class, stress	None*	Plus SBP, HTN treatment, DM, serum TC
Sweden, Swedish Women's Lifestyle and Health Cohort Study[42]	20.0–24.9	None*	Age, sm, dr, edu, age at first birth, use of OC	None*	Plus hx of HTN, DM
Finland, Six Independent Cross-sectional Population Surveys[35]	18.5–24.9	None None	Age, sm, dr, ex, edu, study year, fhx of stroke	None None	Plus SBP, TC, hx of DM
Japan, JALS[15]	<21.0	27.5 25.0	Age, sm, dr	None* None*	Plus SBP, TC
Japan, Hisayama Study[43]	<21.0	25.0 None	Age	None None	Plus sm, dr, ex, SBP, ECG abnormalities, DM, TC, HDLC, TG
Japan, JPHC Study[44]	23.0–24.9	None* 30.0*	Age, study community	None* 30.0*	Plus sm, dr, HTN, DM
China, China Stroke Prevention Project[36]	18.5–24.9	None None	Age, sm, dr, edu	None None	Plus hx of DM, HTN heart disease
China, China National Hypertension Survey[37]	18.5–24.9	25.0 30.0	Age, sm, dr, ex, edu, residence area		
China, Shanghai Women's Health Study[38]	<21.1	26.6*	Age, sm, dr, ex, edu, occupation, salary, meno, use of OC, HRT, aspirin, intake of saturated fat, vegetables, fruits, sodium		
China, Kailuan Study[39]	<22.05	27.7	Age, sex, sm, dr, ex, edu, salary, marital status	None	Plus hx of HTN, DM, HC
Korea, no study name[40]	22.0–23.9	24.0*	Age, sm, dr, ex, salary	26.0*	Plus BP, BG, TC
Korea, Korean Prevention Cancer Study[41]	18.5–19.9	28.0 None*	Age, dr, ex	None None*	Plus FBG, SBP, TC

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Supplementary Files

Supplementary File 1

Figure S1. Bar graphs showing the prevalence of obesity (BMI $\geq$30 kg/m^2) among adults aged $\geq$20 years in countries of the 6 WHO regions of the world in 2008.

Please find supplementary file(s);
http://dx.doi.org/10.1253/circj.CJ-14-0850