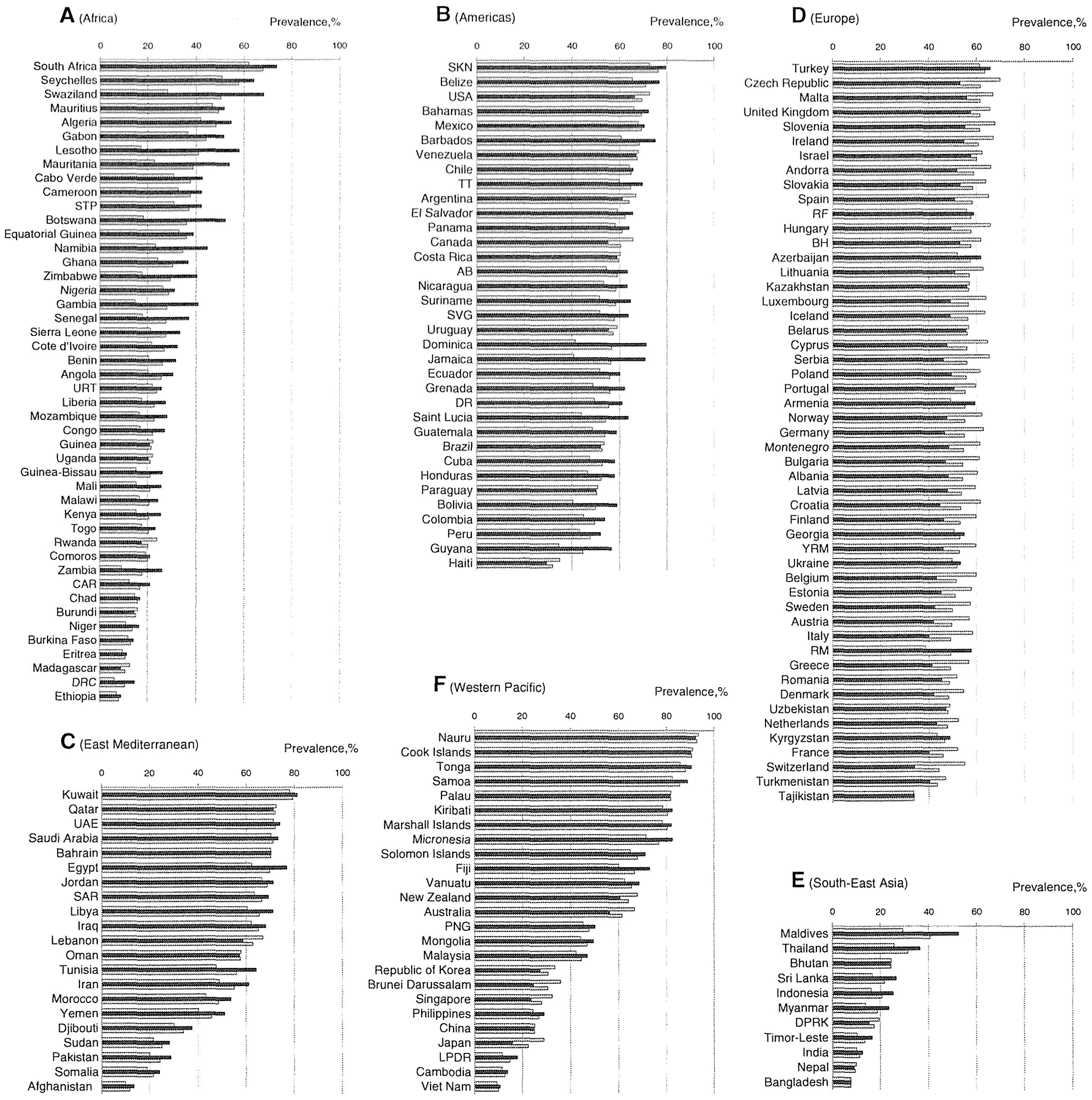

Figure 1. Bar graphs showing the prevalence of overweight/obesity (BMI ≥25 kg/m²) among adults aged ≥20 years in countries of the 6 WHO regions of the world in 2008. (**A**–**F**) Estimates for every country in Africa, the Americas, East-Mediterranean, Europe, South-East Asia, and the West Pacific, respectively, 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.

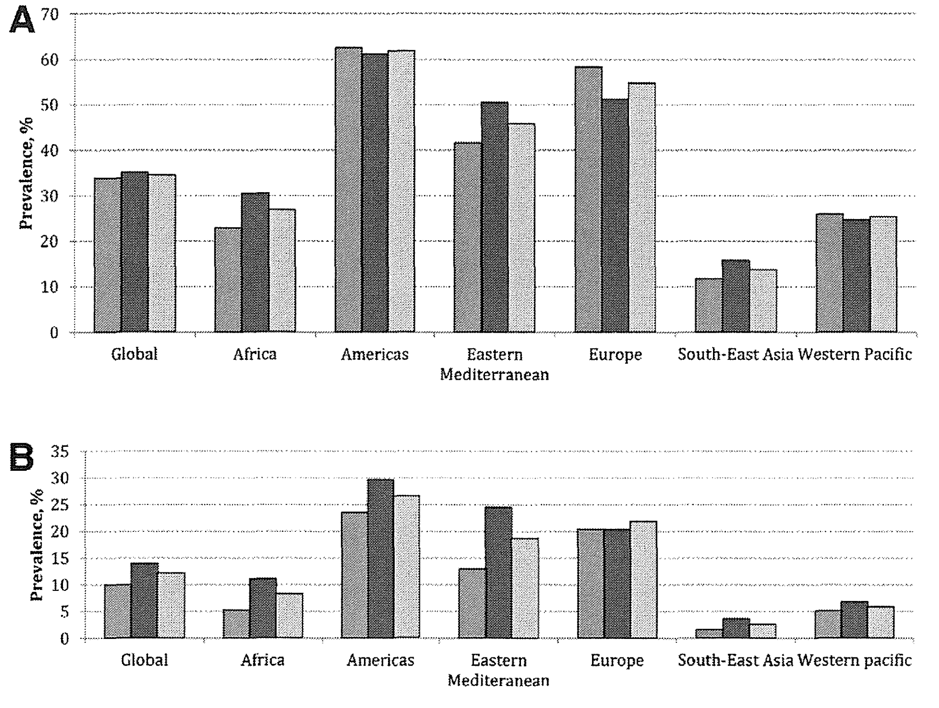

Figure 2. Bar graphs showing the prevalence of overweight/obesity (BMI ≥25 kg/m², A) and obesity (BMI ≥30 kg/m², B) among adults aged ≥20 years in the 6 WHO regions of the world in 2008. Blue, men; red, women; green, total. All estimates are age standardized. BMI, body mass index. Data were obtained 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%

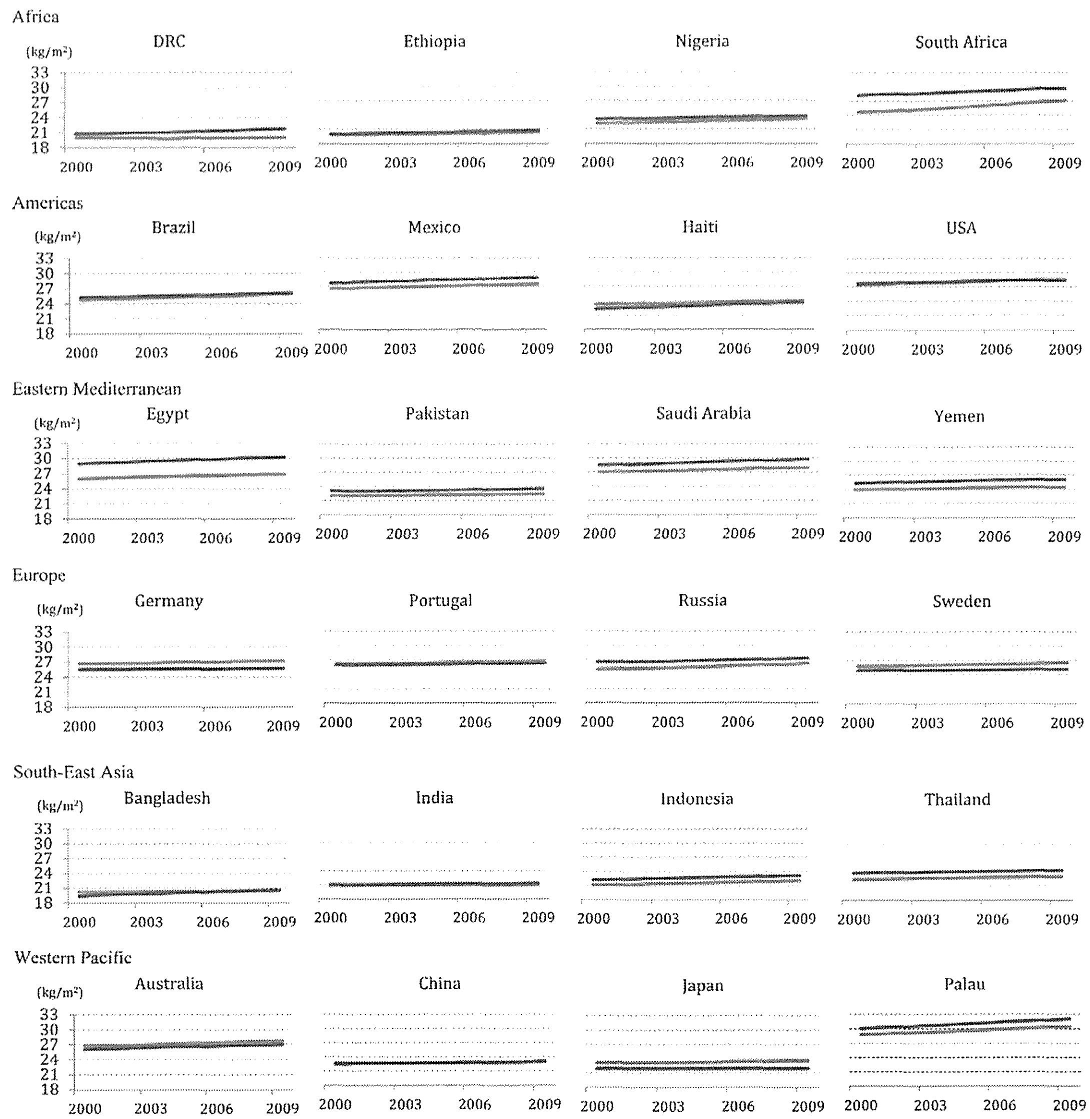

Figure 3. Ten-year (2000–2009) trend of mean BMI in 24 selected countries representing the 6 WHO regions of the world: Africa (represented by Democratic Republic of Congo (DRC), Ethiopia, Nigeria and South Africa); the Americas (represented by Brazil, Haiti, Mexico, and the United States of America (USA)); 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	23.8	Age, sm	23.8	Plus TC
	<22.3	27.6		27.6	
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]	18.5–22.9	23.0	Age	23.0	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, Nurses' Health Study		25.0		25.0	
USA, ARIC Study[28]	<24.7	None	Age, sm, dr, ethnicity, fhx of CHD		
	<23.3	31.0			
USA, Physicians' Health Study[18]	<22.8	25.7	Age, sm, dr, ex, RTA, fhx of MI, multivitamins, aspirin use		
		25.7*			
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*	Age, sm, adjusted FEV1, social class		
		30.0, 30.0*			
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	25.5	Age	27.0	Plus sm, dr, ex, SBP, TC
	<22.8	24.7		24.7	
UK, Scottish Health Cohort Study[20]	18.5–24.9	25.0	Age, sm, dr, year of survey		
		25.0			
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*	Age, sm, plasma LDLC, lipid-lowering medication use, aspirin use
				25.0, 25.0*	
				None, 25.0*	
				25.0, 25.0*	
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	Age, community	None	Plus sm, dr, meno, time since last meal, serum TC
		None		None	
Japan, JALS[15]	<21.0	23.0*	Age, sm, dr	27.5*	Plus SBP, serum TC
		None*		None*	
Japan, JPHC Study[24]	23.0–24.9	30.0, 27.0*	Age	30.0, 30.0*	Plus sm, dr, ex, hx of HTN, DM, public health center, intake of green vegetables, fish
		None, None*		None, None*	
Korea, Korea Medical Insurance Corporation Study[17]	18.0–19.0	23.0	Age, sex, sm, dr, ex, health insurance	23.0	Plus HTN, DM, TC
		25.0*		30.0*	

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/m²	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 Lifestyle 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 Hypertension 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/m² 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 Life-style 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 1960s to 1970s) 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 1960s, 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/m²	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 Lifestyle 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	M
						26,029	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	Mean 9.1	>35	NA	12,560	M
						14,047	W
China, China National Hypertension 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, *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 Life-style 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 Hyperten-sion Survey[37]	18.5–24.9	25.0 30.0	Age, sm, dr, ex, edu, resi-dence 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.

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[Original Article]

Patterns of risk factors related to non-communicable diseases (NCDs) in Asian and Oceania countries by using cluster analysis

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Abstract

Background and Objective

The prevalence of non-communicable diseases (NCD) is increasing in low- and middle-income countries, imposing major public health and development threats. However, there is difference among countries with regard to the patterns of NCD metabolic risk factors. This study aims to categorize the pattern of metabolic risk factors in East Asia, Southeast Asia and Oceania.

Methods

Age-standardized prevalence of obesity, raised blood pressure, raised blood glucose, and raised blood cholesterol for 2008 were obtained from the World Health Organization (WHO) Global Health Observatory Data Repository. We used hierarchical cluster analysis to categorize countries in East Asia, Southeast Asia and Oceania based on the prevalence of NCD metabolic risk factors of each country.

Results

Three patterns of NCD metabolic risk factors were identified. The first pattern showed relatively high prevalence of raised blood cholesterol, while prevalence of obesity, raised blood pressure and raised blood glucose remain relatively low. Most high- and upper-middle-income Asian countries were included in this pattern. The second pattern presented relatively high prevalence of raised blood pressure, although prevalence of obesity, raised blood glucose, and raised blood cholesterol stay relatively low. Most low- and lower-middle-income Asian countries were categorized in this pattern. The third pattern presented high prevalence of obesity and relatively high prevalence of raised blood pressure and raised blood glucose. This pattern included most Pacific island countries.

Conclusions

Policy makers in countries in East Asia, Southeast Asia, and Oceania should take into account for the features of the pattern they are in, when they set priorities for developing effective NCD control measures.

Keywords: Non-communicable diseases, Risk factors, East Asia, Southeast Asia, Oceania, Cluster analysis

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I. Introduction

The prevalence of non-communicable diseases (NCDs), such as ischemic heart diseases, stroke and diabetes, is increasing in low- and middle-income countries along with economic development and changes in the lifestyle and nutritional status. The World Health Organization (WHO) estimated that 7.3 million people died from ischemic heart diseases in 2008, the highest cause of mortality in the world, and 80% of the deaths occurred in low- and middle-income countries[1]. However, the health sector in those countries has not been ready to provide the entire population with affordable long-term treatment or effective preventive interventions to NCDs[2], while maternal and child health services and communicable disease control programs have been successfully extended[3]. Controlling NCDs in low- and middle-income countries would be a key factor for achieving universal health coverage, a global initiative for post-2015 development agenda[4].

While NCDs are common problems throughout the world, priority issues are different depending on the genetic background, lifestyle and environment, and social and economic situation of the population. For example, major issues in the United States are obesity, hyperglycemia, hypercholesterolemia[5], and, as a consequence, atherosclerosis of medium or large arteries. However, in Japan during 1960s and 70s, stroke due to sclerosis of small arteries, which was brought by uncontrolled hypertension, was the highest cause of mortality, despite low obesity prevalence[6]. It would be useful to classify countries in the world according to the priority NCD metabolic risk factors, so that policy makers would be able to set effective control strategies for the population.

This study aims to categorize countries according to the prevalence of NCD metabolic risk factors, and provide policy makers with a clue to set prioritized intervention strategies. As a first step, we chose countries in East Asia, Southeast Asia and Oceania, comprised of various income levels, and were expected to suffer from high NCD mortality[7]. NCDs are gradually recognized as major public health issues in the countries in East Asia and Southeast Asia, where people's lifestyle changed dramatically during the past decades along with the rapid economic development, although obesity prevalence has not been very high yet. In Oceania, obesity prevalence is known to be extremely high, particularly among Pacific islanders[1].

II. Methods

1. Data source

Age-standardized prevalence of obesity, raised blood pressure, raised blood glucose and raised blood cholesterol of 28 countries in East Asia, Southeast Asia, and Oceania were obtained from the WHO Global Health Observatory Data Repository. The Data Repository represents the best estimates for WHO member states by using specific methodology to ensure the data comparability across countries and times[8]. The latest released NCD risk factor prevalence data were those for 2008. Data of the above four NCD metabolic risk factors were widely available from the data source, although the data of other risk factors such as physical activities and diets were often missing.

2. Statistical analyses

Age-adjusted prevalence of obesity, raised blood pressure, raised blood glucose and raised blood cholesterol were standardized to z-scores, which ranged between 0 and 1, to avoid the larger contribution of variable measured in larger ranges than variables with smaller ranges. Hierarchical cluster analysis based on squared Euclidean distance and within groups average linkage was used to identify patterns in terms of similar prevalence[9, 10], followed by the qualitatively checking of the similarity of countries in each cluster with respect to their prevalence of each NCD risk factor.

We considered all the people in component countries in a pattern as divided groups with prevalence and made one combined population, and assumed that the WHO data we used was randomly selected from this combined population. Analysis of variances (ANOVA) was conducted to test the overall difference on means among the patterns, followed by Sidak post hoc comparison procedure to compare the mean performance of each variable for any two patterns. All the statistic analyses were performed by IBM SPSS 20.0 and statistical significance was set at the level of $P < 0.05$.

3. Graphing

Radar plotting is a form of graphing which was reported to be practical and profoundly useful for examining and displaying patterns in multivariate data of medicine researches[11]. To show the characteristics of each pattern, we have drawn radar charts for a typical country from each pattern.

4. Ethical clearance

This study is a part of a study entitled "Multi-Disciplinary Study for Promoting Non-Communicable Disease Control in East Asia and Oceania," funded by Health and Labor Sciences Research Grants (Research on global health issues), Ministry of Health, Labor and Welfare, Japan. The whole study plan was reviewed and approved by the Ethics Review Committee of Nagoya University School of Medicine, Nagoya, Japan (Approval No. 2012-0103).

III. Results

Table 1 shows age-standardized prevalence of obesity, raised blood pressure, raised blood glucose, and raised blood cholesterol for 2008 of the 28 countries in the studied regions. The prevalence of obesity (BMI $\geq$ 30 kg/m^2) ranged from 1.6% (Vietnam) to 71.1% (Nauru). The highest prevalence of raised blood pressure (systolic blood pressure $\geq$ 140 mmHg or on medication) was reported in Vanuatu (47.2%) while Republic of Korea reported the lowest (29.8%). The highest prevalence of raised blood glucose (fasting blood glucose $\geq$ 7.0 mmol/L or on medication) was reported in Marshall Islands (28.7%), while Cambodia reported the lowest (5.1%). The highest prevalence of raised blood cholesterol (total cholesterol $\geq$ 5.0 mmol/L was reported in Cook Islands (59%), and the lowest was in Cambodia (30%).

The dendrogram generated by cluster analysis presents the clustering process among the studied countries (Fig. 1). Based on the z-scores of the four metabolic risk factors, the most similar countries merged step by step, until all countries were combined into a biggest cluster. Heterogeneity among the clusters increased from left to right. Three major clusters were revealed by setting the cut-off at the rescaled distance cluster combine level of 15. The first cluster, comprised of eight high- and upper-middle-income countries most of which located in Asia (Brunei Darussalam, Thailand, Singapore, Japan, Malaysia, Australia, New Zealand, and Republic of Korea). The second cluster included ten low- and lower-middle-income countries (Vanuatu, Mongolia, Lao PRD, China, Vietnam, Indonesia, Myanmar, Philippines, Cambodia, and Papua New Guinea); most of them located in Asia. The third cluster comprised of ten Pacific insular countries (Palau, Tonga, Fiji, Micronesia, Cook Islands, Nauru, Kiribati, Solomon Islands, Samoa, and Marshall Islands).

Table 2 presents the population z-score means on each variable. Overall, differences among the three patterns were observed on each variable after ANOVA was conducted (All $P < 0.05$). The results of multiple comparisons by Sidak t-test are shown in Table 3. The first pattern showed the highest raised blood cholesterol z-score mean, which was significantly higher than the second pattern ($P < 0.001$) and the third pattern ($P = 0.048$). The second pattern had higher raised blood pressure z-score means than the first pattern ($P = 0.027$), although it was not significantly different from that of the third pattern ($P = 0.747$). The third pattern, presented significantly higher z-score means in obesity than other two patterns, and z-scores of raised blood pressure and raised blood glucose were also relatively high.

Characteristics of the three patterns are shown as radar charts of typical countries categorized in each pattern (Fig. 2). Japan was a typical country in the first pattern, which presented high prevalence of raised blood cholesterol and relatively low prevalence of obesity, raised blood pressure and raised blood glucose. Chart of Mongolia showed the typical characteristics of the second pattern with significantly high prevalence of raised blood pressure compared to the first pattern. The remarkable feature of the third pattern was extremely high prevalence of obesity, as shown in the radar chart of Nauru. The prevalence of raised blood pressure and raised blood glucose were also high in the third pattern.

IV. Discussion

In this study, we applied cluster analysis for identifying NCD risk factor patterns. Cluster analysis is a widely used method in medical researches for classifying similar patterns from large data involving many variables. The most similar individuals merged step

Table 1　Age-standardized prevalence of four major NCD metabolic risk factors

	Obesity [a] (%)	Raised blood pressure [b] (%)	Raised blood glucose [c] (%)	Raised blood cholesterol [d] (%)
East Asia				
China	5.1	38.6	9.5	33.4
Japan	4.5	36	5.9	57.1
Mongolia	16.4	47	9.9	37.3
Republic of Korea	7.3	29.8	6.1	42.5
Southeast Asia				
Brunei Darussalam	7.9	34.4	7.4	55.2
Cambodia	2.3	31.5	5.1	30
Indonesia	4.7	41	6.9	35.8
Lao PDR	3	37.3	7.4	31.4
Malaysia	14.1	38	11.4	52.1
Myanmar	4.1	42	6.6	30.4
Philippines	6.4	37.2	6.6	43.3
Singapore	6.4	34.6	6.4	57.5
Thailand	8.5	34.2	7.2	55.5
Vietnam	1.6	36.8	7.7	36.1
Oceania				
Australia	25.1	31.8	8.1	55.2
Cook Islands	64.1	43.6	20.8	59
Fiji	31.9	41.6	14.8	53.2
Kiribati	45.8	37.4	24.2	35.5
Marshall Islands	46.5	36.8	28.7	46.1
Micronesia	42	41.8	17	48.1
Nauru	71.1	43.9	14	46.2
New Zealand	27	32.6	9.9	56.2
Palau	50.7	40.1	18.2	54.7
Papua New Guinea	15.9	32.1	15	38.2
Samoa	55.5	42.7	22.4	34.6
Solomon Islands	32.1	37.4	17.7	33.2
Tonga	59.6	41.1	18.2	49.7
Vanuatu	29.8	47.2	9.4	37.6

[a]Body Mass Index ＞= 30 kg/m^2; [b]Systolic Blood Pressure ＞= 140mmHg or on medication;
[c]Fasting Blood Glucose ＞= 7.0 mmol/L or on medication; [d]Total Cholesterol ＞= 5.0 mmol/L.
Data source: WHO Global Health Observatory Data Repository for 2008

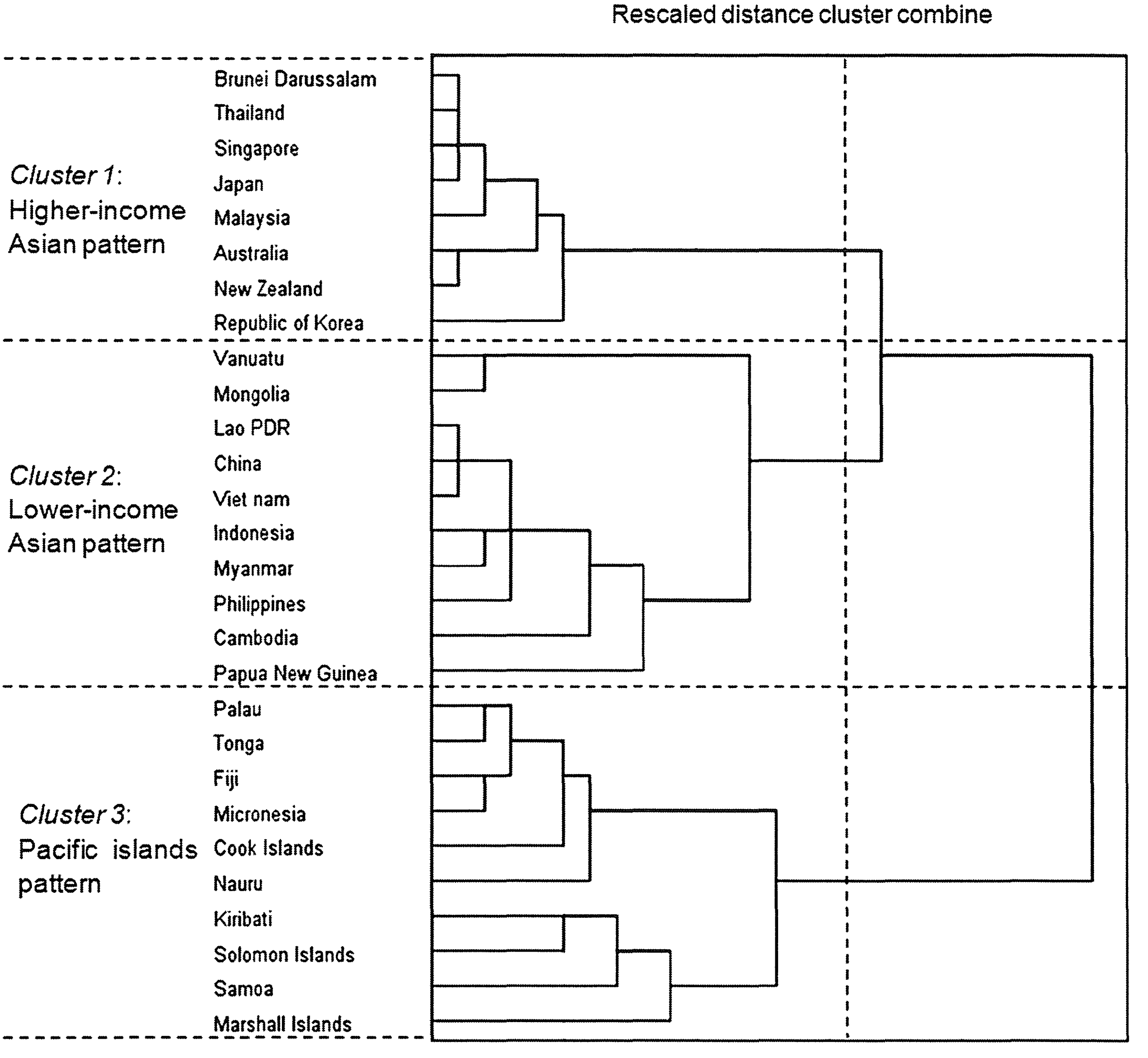

Figure 1 Dendrogram of the patterns of NCD metabolic risk factors

Table 2 Characteristics of the three patterns of NCD metabolic risk factors

	Obesity [a] z-score means (SD)	**Raised blood pressure** [b] z-score means (SD)	**Raised blood glucose** [c] z-score means (SD)	**Raised blood cholesterol** [d] z-score means (SD)
First pattern Higher-income Asian pattern (n=8)	-0.5533 (0.40)	-0.9142 (0.55)	-0.6871 (0.30)	0.9608 (0.50)
Second pattern Lower-income Asian pattern(n=10)	-0.7196 (0.41)	0.1963 (1.16)	-0.5925 (0.43)	-0.9275 (0.42)
Third pattern Pacific island pattern (n=10)	1.1622 (0.60)	0.5351 (0.57)	1.1421 (0.70)	0.1589 (0.91)
ANOVA	F=45.046, P<0.001*	F=7.278, P=0.003*	F=38.111, P<0.001*	F=18.866, P<0.001*

[a]Body Mass Index ≥ 30 kg/m^2; [b]Systolic Blood Pressure ≥ 140mmHg or on medication;
[c]Fasting Blood Glucose ≥ 7.0 mmol/L or on medication; [d]Total Cholesterol ≥ 5.0 mmol/L.
* P < 0.05

Table 3　Multiple comparison for any two patterns by Sidak t-test

Multiple comparison groups			Obesity [a]		Raised blood pressure [b]		Raised blood glucose [c]		Raised blood cholesterol [d]	
I		J	Mean difference (I-J)	P	Mean difference (I-J)	P	Mean difference (I-J)	P	Mean difference (I-J)	P
Higher-income Asian pattern	vs	Lower-income Asian pattern	0.166	0.856	-1.111	0.027*	-0.095	0.974	1.888	<0.001*
Higher-income Asian pattern	vs	Pacific island pattern	-1.715	<0.001*	-1.449	0.003*	-1.829	<0.001*	0.802	0.048*
Lower-income Asian pattern	vs	Pacific island pattern	-1.882	<0.001*	-0.339	0.747	-1.735	<0.001*	-1.086	0.003*

[a]Body Mass Index ≥ 30 kg/m^2; [b]Systolic Blood Pressure ≥ 140mmHg or on medication;
[c]Fasting Blood Glucose ≥ 7.0 mmol/L or on medication; [d]Total Cholesterol ≥ 5.0 mmol/L.
* $P < 0.05$

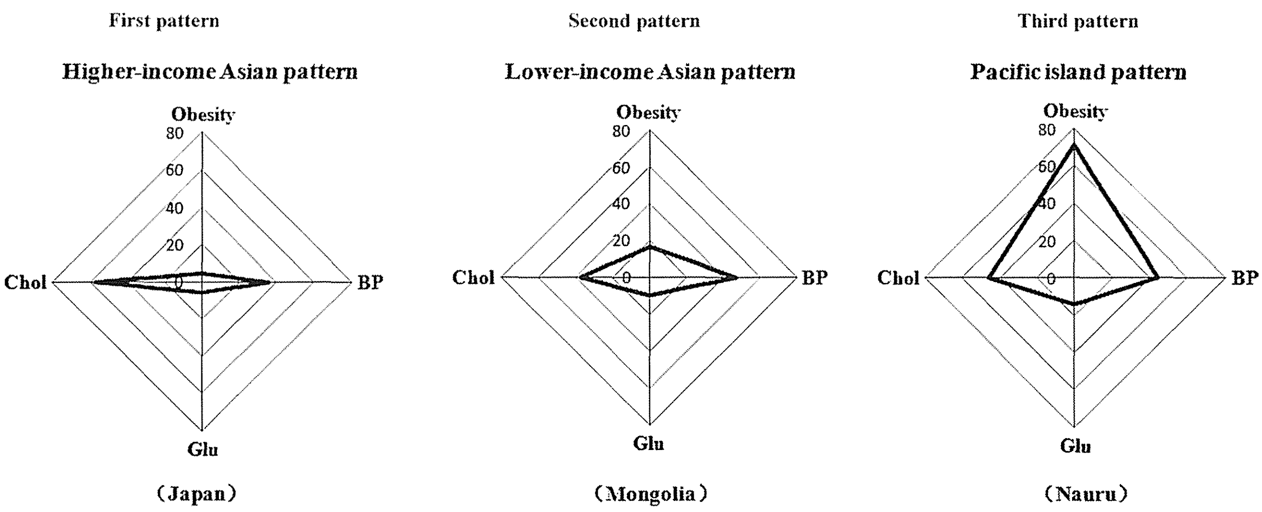

Figure 2.　Radar charts of the three patterns of metabolic risk factors

Typical countries of each pattern are shown. BP: raised blood pressure; Glu: raised blood glucose; Chol: raised blood cholesterol. The vertical and horizontal scales show the prevalence of each factor.

by step, until finally all individuals aggregate into the biggest cluster. Previous applications of cluster analysis were found in identifying patterns of behaviors[9, 10], dietary[12], or in genetic expressions[13]. These studies suggest that cluster analysis may be useful in characterizing large data into subgroups for identifying patterns with different features.

Our analysis revealed the three patterns of four major NCD metabolic risk factors among countries in East Asia, Southeast Asia and Oceania. We found that most countries in each pattern shared common economic and geographical characteristics, and therefore we propose to label the three patterns according to the income level and geographic characteristics of the majority of the countries categorized in each pattern. We propose to name the first pattern as Higher-income Asian pattern, the second pattern as Lower-income Asian pattern, and the third patter as Pacific island pattern. Higher-income Asian pattern presented relatively high prevalence of raised blood cholesterol, while prevalence of obesity, raised blood pressure and raised blood glucose remain relatively low. Countries which show this pattern are mostly high- and upper-middle-income countries in the regions. It is known that total blood cholesterol is an independent strong risk factor for ischemic heart disease[14, 15]. Some cause-specific mortality reports showed similar feature with our result. Many Higher-income Asian pattern countries, such as Japan, Korea and Singapore, reported the increase in age-adjusted mortality for ischemic heart disease, in spite of the dramatically decline in stroke mortality[16]. Therefore, interventions to reduce blood cholesterol levels of the people should be a priority in these countries for preventing expected high morbidity and mortality from ischemic heart diseases. Possible interventions include promoting to take dietary fibers but not to take excess amount of saturated fats, screening blood cholesterol levels of people, and providing continuous medical treatment for hypercholesterolemia.

Lower-income Asian pattern presented relatively high prevalence of raised blood pressure, although prevalence of obesity, raised blood glucose, and raised blood cholesterol stayed relatively low. Most of low- and lower-middle-income countries in Asia are categorized in this pattern. Raised blood pressure is the most significant risk factor of stroke, which bears two thirds of the stroke burden globally[17]. National income was proved to be the strong predictor of stroke mortality, and low income countries have 3.5 times higher stroke mortality rates than those of middle- and high-income countries. For example, Mongolia, a Lower-income Asian pattern country, was reported to have about 5 times higher mortality rate of stroke than that of Australia or New Zealand, which were categorized as Higher-income Asian pattern countries[18]. It is urgently needed for those countries to control the blood pressure of people by reducing dietary salt intake through proper health and nutrition education, screening blood pressure regularly, and ensuring access to affordable lifelong antihypertensive treatment.

Pacific island pattern, observed uniquely among low- and middle-income insular countries in Oceania, exhibited high prevalence of obesity, relatively high prevalence of raised blood pressure and raised blood glucose. People in those countries are likely to suffer from high morbidities and mortalities from stroke and diabetes mellitus in the near future, unless effective control measures against obesity, raised blood pressure and raised blood glucose are taken. Integrated multi-sectoral interventions for improving diet habits and physical activities are urgently required. For example, it is needed for the people in these countries to increase intakes of vegetables and fruits and to reduce intakes of canned or processed meat with high fat and salt concentration. Therefore, not only school and community based nutritional education programs, but also interventions to the food production and marketing systems would be required simultaneously. In spite of the alarming situations of NCD problems, systematic studies on NCD mortalities and morbidities as well as detailed studies of lifestyle risk factors in low- and middle-income Pacific island countries were very limited. Further work is urgently needed to develop evidence-based NCD control strategies in these countries.

One of the interesting findings of this study was that two Pacific island countries, Vanuatu and Papua New Guinea, were categorized in Lower-income Asian pattern rather than Pacific island pattern. It means that the two countries might have relatively lower prevalence of obesity and raised blood glucose than the other Pacific islands countries. This phenomenon might be attributed to relatively high level of physical activities in Vanuatu[19] or genetic difference among Pacific islanders[20]. Since detailed NCDs related risk factor prevalence of those two countries and other Pacific islands countries were not available, the reasons why the two countries present different features require further studies.

Although we categorized countries in East Asia, Southeast Asia, and Oceania into three patterns of NCD metabolic risk factors, countries are unlikely to stay in the same pattern forever. People's lifestyles and nutritional status are changing along with the social and economic development, and so will the prevalence of NCD metabolic risk factors. Systematic public health interventions are also expected to bring dynamic changes in NCD metabolic risk factors.

For example, Japan is currently categorized in the Higher-income Asian pattern; however, it had high prevalence of hypertension and highest stroke mortality in the world in 1960s and 70s[6, 21], similar to the countries categorized in the Lower-income Asian pattern. Systolic blood pressures of Japanese people have been successfully lowered through systematic public health interventions, including health education and nutrition consultations for reducing salt intake, screening blood pressures in the local communities and workplaces, and providing affordable continuous anti-hypertensive treatment[6, 22]. This implies that the proper interventions would make difference in the prevalence of NCD risk factors, and could reduce NCD mortalities and morbidities.

The changes in the pattern of NCD metabolic risk factor became apparent two to three decades after the period of rapid economic development in Japan. This suggests that low- and lower-middle-income countries in East Asia and Southeast Asia categorized in Lower-income Asian pattern may shift to be categorized in the Higher-income Asian pattern, 20 to 30 years after the ongoing dramatic economic growths. Therefore, unless systematic interventions for controlling hypertension are implemented immediately, these countries may suffer from dual burdens of high prevalence of raised blood pressures and raised blood cholesterol in the near future.

This study is the first step to highlight the features of NCD metabolic risk factors. Based on the estimated prevalence data obtained from the WHO database, we have identified three patterns of NCD metabolic risk factors. Categorizing into patterns could urge policy makers to develop appropriate joint or common strategies in the region based on the current risk factor status.

However, this study had several limitations. First, we chose single database to ensure the data comparability across countries and times[8], however, the data might not be representative of the whole population in each country. Sub-regional data within each county were not available from the database. For example, in China, NCD metabolic risk factors might be significantly different between residents in rich urban cities and poor farmers in remote areas. Second, other factors which might have relevant effects on establishing NCD pattern, such as diet, physical activity, and socio-economic factors, were not included in the analyses of this study, as the comparable data were unavailable or missing in significant number of the observed countries.

As a first step, we targeted only East Asia, Southeast Asia and Oceania regions. Next studies should cover larger Asian areas, where NCD metabolic risk factor feature is diverse. For example, obesity prevalence in Middle East and Central Asia is known to be much higher than that in East and Southeast Asia[8]; and comparing to that of East Asian, obesity for South Asians was reported to have different contribution to cardiovascular diseases[23], and cardiovascular disease mortality was also higher in South Asian countries[24]. It would also be useful to extend the analysis to other regions such as Africa and Latin America. Gender differences need to be investigated as well[25], although this study used estimated prevalence for both sexes to ensure comparability across countries.

V. Conclusion

Three patterns of the four major NCD metabolic risk factors were identified in our study. The patterns were labeled as: Higher-income Asian pattern, Lower-income Asian pattern and Pacific island pattern according to the income level and geographic characteristics of the countries categorized in each cluster. Countries categorized in each pattern should set priorities for effective NCD control strategies, taking into account of the features of the pattern. Possible pattern transition in the future should also be taken into consideration.

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