Latent Classes of Metabolic Syndrome in the Korean Population: Identification and Comparison of Classes among Different Educational Groups*

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Although a series of debates about inherent and practical limitations exist, factor analysis has successfully produced reasonably consistent results that revealed an underlying relationship between the constitutional components of metabolic syndrome. In this paper, the authors tried to achieve different goals: to identify distinctive underlying groups of at-risk people instead of hidden factors with regard to metabolic syndrome and to examine if there is any discrepancy based on educational attainment. By studying 757 men and 847 women who participated in the Korean National Health and Nutritional Survey in 2001, latent class analysis with a built-in goodness-of-fit test was used to identify underlying classes of the Korean adult population. Among males, four distinctive classes were revealed: "healthy," "blood pressure only," "lipid only," and "risky." The male respondents who were younger than 41 shared exactly the same latent classes without any difference. However, among males with an age of 41 years or older, less-educated men who did not have a high school diploma made up a much higher proportion of the "risky" class when compared with highly educated males (39% vs. 16%). Women also had four similar classes. Among females who were 40 years old or younger, there was no discrepancy across the different educational groups. However, for the females who were 41 or older, less-educated people composed a smaller proportion of the "healthy" class (36% vs. 51%) and developed a new class, "very risky" (12%). Although metabolic syndrome itself rarely has self-recognized pain or symptoms, it has been known as being systematically linked to various chronic diseases such as cardiovascular disease or type 2 diabetes. Among young Korean adults, there was no discrepancy observed based on educational level but in the old population, people who were less-educated either had a higher proportion of 'risky' group or

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developed a new 'very risky' group. Proper diagnostics and education needs to be promoted among old less-educated people.

Keywords: metabolic syndrome X, educational disparity, Korea, latent class analysis

BACKGROUND

Studies on population health have successfully accumulated two important facts. First, the process of being ill and healthy is steadily affected by various sociological factors such as income level, working conditions, retirement, social support, depression, marital status, and educational level (Berkman and Kawachi 2000). Numerous studies proved that various sociological dynamics have strong and systematic effects on the prevalence of diverse diseases and eventually mortality rates of the population and thus also showed the existence of health inequalities (Ross and Wu 1996; Lawlor, Ebrahim, and Smith 2002; Khang and Kim 2005a). Although the exact mechanisms are still waiting to be revealed, most aspects of everyday life are believed to be governed and thus, unequally patterned by socio-economic statuses, which in turn produce unequal distribution of health and illness (Berkman and Kawachi 2000; House 2001; Wilkinson 1997). According to a Korean study that used the same data of this paper, with compared to high school graduates, people with lower educational level had about 1.7 times higher mortality rates and people with lower-quartile income level were 2.4 times more likely to die with compared to people with higher-quartile income (Khang and Kim 2005b).

Second, major health problems of modern societies are not acute diseases any more but chronic diseases. Although modern medicine cannot solve all problems related with acute diseases, most health problems people face everyday life are now chronic ones (House 2001). South Korea is not the exception. Four leading killers are cancer, cerebrovascular disease, cardiac disorder, and diabetes and these four are responsible for more than half of deaths in Korea (Lee 2005). Chronic diseases are also systematically affected by socio-economic statuses (Dalstra et al. 2005; Ben-Shlomo and Kuh 2003) and the prevalence among Seoul citizens follows the same pattern. After controlling for age, the odds ratio of chronic diseases for men was 2.05 (95% confidence interval [CI], 1.64-2.61), for women 2.27 (95% CI, 1.89-2.72) among those with the lowest-educated group compared to the highest-educated group (Kim and Kim 2003). This study focuses on metabolic syndrome that is believed to be especially responsible for cardiac diseases and diabetes.

Although we have accumulated many studies on metabolic syndrome, from methodological point of view, most empirical studies have relied on factor analysis. Exploratory factor analysis was encouraged by the Edward et al.'s study in 1994 (Edwards et al. 1994), and then Meigs et al.'s (1997) study used and argued for confirmatory factor analysis in 1997 (Meigs et al. 1997).

Confirmatory factor analysis is thought to have a few advantages over exploratory analysis: the former uses several types of goodness-of-fit tests to compare theory-based competing models of metabolic syndrome to ensure generalizability (Lawlor et al. 2004; Shah, Novak, and Stapleton 2006; Shen et al. 2003). Many studies have relied on confirmatory analysis to reveal underlying factors, and these studies have produced somewhat consistent results (Li et al. 2007; Novak et al. 2003). First, four risk factors (components) have been constantly identified for metabolic syndrome: abdominal obesity, dyslipidemia, hyperglycemia, and hypertension. Second, when people show these components together as a syndrome rather than separately, they are more likely to develop diverse chronic diseases such as cardiovascular disease, type 2 diabetes and prostate cancer (Eckel et al. 2005; Girman et al. 2005; Gray et al. 1998; Håheim et al. 2006; Isomaa et al. 2001; Lempiäinen et al. 1999; Liese et al. 1998; Wilson et al. 1999). Considering the current global epidemic of obesity and diabetes (Zimmet, Alberti, and Shaw 2001), metabolic syndrome warrants more attention.

Rather than revealing the underlying structure of the risk components of metabolic syndrome, this study tried to identify mutually exclusive groups of people with regard to a different combination of components based on latent class analysis. Latent class analysis can identify distinctive, hidden classes of people who have different configurations of risk components (McCutcheon 1987): for example, a group of people might have no risk components at all, while another group of people show only hypertension without any other components. In purpose, latent class analysis is analogous to cluster analysis: the former is used to discover groups or types of cases based on observed data, and also to assign cases to groups (Clogg 1995; Dayton 1998; Hagenaars 1993; McCutcheon et al. 1999). Additionally, latent class analysis is considered to be a categorical-data counterpart to factor analysis in the sense that both can be regarded as methods for data reduction: factor analysis is used to reduce the number of variables, and latent class analysis is employed to reduce the number of classes. Latent classes, like factors, are unobserved constructs inferred from observed data. However unlike cluster analysis or factor analysis, latent class analysis has three distinctive features. First, it can fully take into account of non-linear relationship between risk components in the data while, for example, factor analysis must assume that factors are linear transformations of original risk component variables. Recognizing this limitation, some researchers adopted self-organizing map (SOM) algorithm instead of factor analysis to deal with complex non-linear processes in the metabolic syndrome (Valkonen et al. 2002). Second, latent class analysis has a robust built-in goodness-of-fit test. Thanks to this test, we can make it sure that our models fit to the data and even choose the best among data-fitting models (Clogg 1995; Dayton 1998; Hagenaars 1993; McCutcheon et al. 1999). Third, however it can deal only with categorical variables and thus, we have to transform risk component variables into categorical ones.

Once identifying latent classes of people with regard to the components of metabolic syndrome, this paper also tried to examine if people with different educational levels had

difference latent classes in Korea. Confirmatory and simultaneous latent class analyses were adopted for this purpose. Many studies successfully accumulated evidence to show that low socio-economic status groups have higher prevalence of risk components of metabolic syndrome (Ebrahim et al. 2004; Facchini et al. 1994; Golden et al. 2002; Horsten et al. 1999; Kim et al. 2005; Lawlor et al. 2002; Santos et al. 2008). However, a series of latent class analyses enabled this paper to make unique contributions. First, it revealed that there exist different latent groups of people with regard to the risk components of metabolic syndrome. Previous studies have only focused on if someone was infected with metabolic syndrome or not and what kinds of risk variables increased the odds of being infected. Based on a set of latent class analyses, however, this paper has successfully identified some latent classes that have not developed metabolic syndrome yet but still contains some risky components. This finding could be very informative for preventive strategies. Second, the goal of this work is to identify empirically existing groups of people rather than to identify a set of risk-related variables. Furthermore, all the statistical models that identified the latent groups of people were tested with built-in goodness-of-fit test that is not available in the OLS regressions or factor analyses.

MATERIALS AND METHODS

This study was based on the Korean National Health and Nutrition Examination Survey of 2001 (KNHNES) conducted by the Korean Ministry of Health and Welfare (Ministry of Health and Welfare 2002). Using household registries, the subjects were selected from non-institutionalized civilians by a stratified multistage probability sampling design based on geographical area, sex and age groups. The KNHNES was composed of four modules: (1) a household survey for basic demographics and health status, (2) an individual survey for health-related behaviors within a household, (3) a diet survey for the last 24 hours, and (4) an anthropometric and clinical examination. Since the survey was based on stratified sampling using individual surveys within each household, we randomly selected only one family member from each household between 20 and 60 years of age to receive the anthropometric and clinical examination in order to maintain the representativeness of the sample. We also excluded people who suffered from diabetes because they were more likely to already have metabolic syndrome. The final sample was comprised of 757 men and 847 women in Korea.

In this study, the metabolic syndrome was defined according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) that suggested five metabolic components and assumed that metabolic syndrome has three or more abnormal components. We adjusted NCEP ATP III in two manners. First, we used a cut-off value of waist circumference (WC) for an Asian population (Inoue and Zimmet 2000). We also included both systolic and diastolic blood pressures individually because the two should not be considered

parallel measures: the two blood pressure components are known to have different physiological determinants and thus, only have a moderate correlation (Franklin et al. 1997; Franklin et al. 2001; Staessen et al. 1990; Staessen et al. 1992). In our sample, the correlation coefficient between the two was 0.77, which is not extremely high. Therefore, we decided to include both components of blood pressure in this study. As a result, each metabolic component was considered to be risky if (1) waist circumference (WC) was greater than or equal to 90cm for men or greater than or equal to 80cm for women, (2) systolic blood pressure (SBP) was higher than 130mm Hg, (3) diastolic blood pressure was lower than 85mm Hg (DBP), (4) triglycerides (TG) were higher than or equal to 150mg/dL, (5) HDL-cholesterol was lower than 40mg/dL for men or lower than 50mg/dL for women, or (6) fasting glucose (FG) was higher than or equal to 110mg/dL.

ANALYSIS

Since we used dichotomized criteria for each of the six risk components of metabolic syndrome, in principle, up to 64 (i.e., 2^6) mutually exclusive groups of people who develop different configurations of metabolic syndrome risks could exist. We adopted a series of three types of latent class analyses to examine latent classes in general Korean population. First, an exploratory latent class analysis should answer the following question: "How many unobserved classes exist where members of the same class show a similar configuration of risk components?" For example, one possible latent class would be a group of people who are abnormal only in the WC dimension but normal in all the other risk factors. After we identify the number of latent classes, confirmatory latent class analysis can determine if the proportion of a certain class is identical across different socio-demographic groups, such as the educational groups in our study. Finally, we adopted a simultaneous latent class analysis to examine if a class composed of highly educated people could be identical to a class of less-educated people. Because the prevalence of metabolic syndrome differs by age and sex (Azizi et al. 2003; Ford et al. 2002; Kim et al. 2004; Onat et al. 2003; Park et al. 2004), we divided our sample into four mutually exclusive sub-groups: males 40 years old or younger, males who were 41 years of age or older, females 40 years old or younger, and females who were 41 years of age or older. Although there is no single age cut that is known as a universal criterion for the analysis of metabolic syndrome but we decided to use age of 40 as a cut since there were a couple of empirical studies on metabolic syndrome where age of 40 was used as a criterion

[1] It would be possible to have more refined criterion of age in the statistical models of continuous variables. However, the latent class analyses of more than two age categories must lead to too complicated results to interpret. Instead of four sub-groups, then we have to deal with six sub-groups and the number of models we have to test against the goodness-of-fit would be too many and the results could be beyond easy interpretation.

(Fujimoto et al. 2000; Kim et al. 2004). We applied our set of analyses to each of these four sub-populations.[1] Additionally, we tested confirmatory and simultaneous latent class analyses in each group to determine if there were any systematic differences with regard to latent classes between different educational groups. After examining the empirical distribution of educational levels for each sex, we decided to apply different criteria to each sex: among males, people with a bachelor's degree were classified as highly educated, while females with high school diplomas were regarded as highly educated.

RESULTS

Young Males

We identified four latent classes among young Korean males. Even though a five-class or a six-class model had a better fit (higher p-value), the four-class model is the better model for our study since it requires fewer parameters for the estimation (more degrees of freedom) for almost the same goodness-of-fit. The best model is determined by pair-wise comparisons of models based on the difference in "log-likelihood X^2" and "degrees of freedom": the sampling distribution of the differences also follows X^2 distribution which makes the comparison easy. As a result of these comparisons based on X^2 tests, we can conclude that a four-class model is the best. Therefore, the exploratory latent class analysis confirmed the existence of four latent classes of metabolic syndrome among young Korean males.

We examined each class so we could understand their characteristics. Figure 1 shows our four mutually exclusive classes: the healthy class, the blood-pressure-only class, the lipid-only class, and the risky class. The healthy class of young males had virtually no abnormal metabolic risk factors. The blood-pressure-only class had blood pressure risk factors alone. About 60 percent of people in this class had abnormal systolic blood pressures, and 57 percent had risky diastolic blood pressures without any other serious metabolic risk factors. The majority of the lipid-only class had problematic levels of triglycerides and HDL-cholesterol. Participants in the risky class had all the metabolic risk factors in general except for fasting glucose. Only about 22% of the risky class had a problematic fasting glucose level.

Table 1 also shows the results of advanced latent class analysis, including both confirmatory and simultaneous latent class analysis. First, confirmatory analysis examines if the proportion of each class previously identified differs between less-educated people (who do not have a bachelor's degree) and highly educated people. The best fitting model confirms that there is no difference. Second, we also investigated whether any different classes existed across different educational groups. The model that assumes that all classes are identical is the best-fitting model. These two latent class analyses enable us to conclude that, regardless of educational level, young Korean males can be divided into four mutually exclusive types of

Table 1. Latent Class Analyses of Metabolic Syndrome among Young Males

Exploratory Latent Class Analysis	L^2	X^2	DF	*p*-value
Two-class model	127.24	151.57	50	0.00
Three-class model	47.16	55.78	43	0.09
Four-class model[a]	28.27	33.24	36	0.65
Five-class model	24.75	27.27	29	0.71
Six-class model	20.92	21.69	22	0.71
Confirmatory Latent Class Analysis[b]	**L^2**	**X^2**	**DF**	***p*-value**
M1: The proportions of four classes are different.	45.75	53.42	72	0.972
M2: The proportions of four classes except the "healthy" class are different.	46.26	53.79	73	0.975
M3: The proportions of four classes except the "blood pressure only" class are different.	45.87	51.58	73	0.986
M4: The proportions of four classes except the "lipid only" class are different.	46.53	54.18	73	0.982
M5: The proportions of four classes except the "risky" class are different.	45.69	53.27	73	0.986
M6: The proportions of four classes are identical[a].	46.80	50.05	75	0.997
Simultaneous Latent Class Analysis[c]	**L^2**	**X^2**	**DF**	***p*-value**
M6+ if the configurations of risk components in four classes are different.	46.80	50.05	75	0.997
M6+ if the configurations of risk components in four classes, except the "healthy" class, are different.	53.84	54.93	81	0.996
M6+ if the configurations of risk components in four classes, except the "blood pressure only" class, are different.	51.16	57.95	81	0.980
M6+ if the configurations of risk components in four classes, except the "lipid only" class, are different.	53.48	62.05	81	0.951
M6+ if the configurations of risk components in four classes, except the "risky" class, are different.	49.43	52.29	81	0.994
M6+ if the configurations of risk components in four classes are identical[a].	73.64	77.55	99	0.960
Final Best Model: M6+ if the configurations of risk components in four classes are identical				

Notes | L^2 = likelihood ratio, X^2 = Pearson's X^2, DF = degrees of freedom

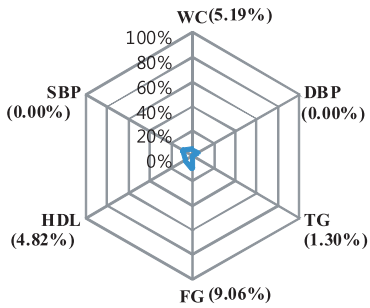
[a] Best Model in each analysis.

[b] A statistical test if the proportions of classes are identical between the less-educated and the highly educated.

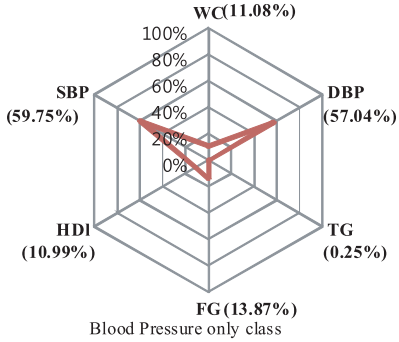
[c] A statistical test if the configurations of risk components in each class are identical between the less-educated and the highly educated.

people with regard to six metabolic syndrome risk factors: "healthy," "blood-pressure-only," "lipid-only," and "risky." Each class constituted 30.4%, 11.8%, 36.1%, and 19.5% of the population, respectively. It is notable that over one-third of young Korean males fell into the lipid-only class; although young Korean males were free from metabolic syndrome in general, many young men still develop lipid-related risks.

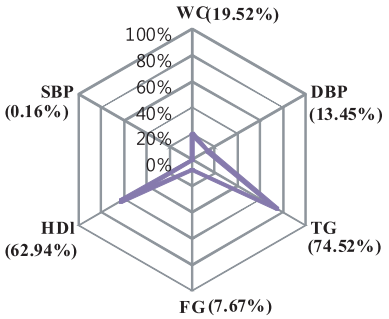
Figure 1. Four Latent Classes among Young Males (40 years of age or younger)



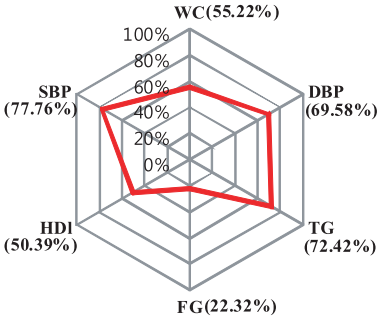
Healthy class
30.4% of Less Educated belong to healthy class[a]
30.4% of Highly Educated belong to healthy class [b]



Blood Pressure only class
11.8% of Less Educated belong to Blood Pressure only class
11.8% of Highly Educated belong to Blood Pressure only class



Lipid only class
36.1% of Less Educated belong to Lipid only class
36.1% of Highly Educated belong to Lipid only class



Risky class
19.5% of Less Educated belong to Risky class
19.5% of Highly Educated belong to Risky class

Notes | WC = waist circumference, SBP=systolic blood pressure, HDL = HDL-cholesterol, FG = fasting glucose, TG = triglyceride, DBP = diastolic blood pressure.
[a] Less educated: person without bachelor's degree
[b] Highly educated: person with bachelor's degree or high
Each hexagon summarizes the proportion of people in each class who developed a risky level in each of the six metabolic syndrome risk factors. The distance from the origin shows the proportion of people who developed a risky level for each component.

Old Males

An exploratory latent class analysis confirmed that four latent classes existed among older Korean males. Table 2 showed that a four-class model is undoubtedly the best based on X^2-test.

A confirmatory analysis in Table 2 revealed that, unlike young Korean men, Korean men older than 41 years did not share the identical proportions of each class between different educational levels. A subsequent, simultaneous analysis showed that the configurations of risk components in each class were identical. These results are summarized in Figure 2.

Table 2. Latent Class Analyses of Metabolic Syndrome among Old Males

Exploratory Latent Class Analysis	L^2	G^2	DF	*p*-value
Two-class model	88.56	93.27	50	0.000
Three-class model	54.94	50.22	43	0.209
Four-class model[a]	39.23	37.49	36	0.493
Five-class model	29.72	28.43	29	0.737
Six-class model	20.00	18.18	22	0.898
Confirmatory Latent Class Analysis[b]	**L^2**	**G^2**	**DF**	***p*-value**
M1: The proportions of four classes are different[a].	55.66	54.01	72	0.968
M2: The proportions of four classes except the "healthy" class are different.	62.43	60.80	73	0.954
M3: The proportions of four classes except the "blood pressure only" class are different.	62.32	62.75	73	0.934
M4: The proportions of four classes except the "lipid only" class are different.	66.44	66.80	73	0.903
M5: The proportions of four classes except the "risky" class are different.	60.05	59.93	73	0.974
M6: The proportions of four classes are identical.	66.92	67.33	75	0.921
Simultaneous Latent Class Analysis[c]	**L^2**	**G^2**	**DF**	***p*-value**
M1+ if the configurations of risk components in four classes are different.	55.66	54.01	75	0.968
M1+ if the configurations of risk components in four classes, except the "healthy" class, are different.	65.91	64.53	81	0.910
M1+ if the configurations of risk components in four classes, except the "blood pressure only" class, are different.	66.85	60.54	81	0.983
M1+ if the configurations of risk components in four classes, except the "lipid only" class, are different.	76.61	71.25	81	0.857
M1+ if the configurations of risk components in four classes, except the "risky" class, are different.	67.21	61.04	81	0.966
M1+ if the configurations of risk components in four classes are identical[a].	89.82	85.10	99	0.779
Final Best Model: M1+ if the configurations of risk components in four classes are identical				

Notes | L^2 = likelihood ratio, X^2 = Pearson's X^2, DF = degrees of freedom

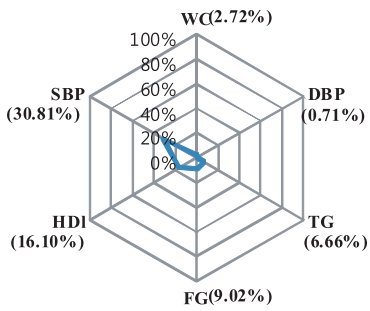
[a] Best Model in each analysis.

[b] A statistical test if the proportions of classes are identical between the less-educated and highly educated.

[c] A statistical test if the configurations of risk components in each class are identical between the less-educated and the highly educated.

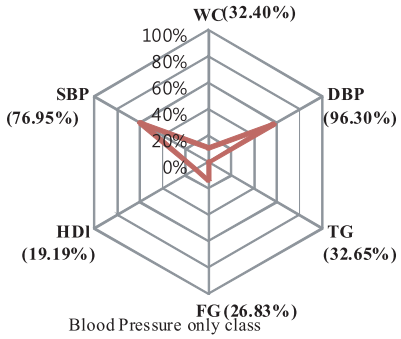
First, just like young Korean men, older Korean men had four similar latent classes of metabolic syndrome: the healthy class, the blood-pressure-only class, the lipid-only class, and the risky class. Second, although all ages of Korean men shared the same types of classes in general, the characteristics of the blood-pressure-only group were somewhat different, especially with regards to the diastolic blood pressure. Approximately 96% of older Korean men in the blood-pressure-only class showed risky diastolic blood pressure, while only 57% of young Korean men had a similar risk level. Third, unlike young Korean men, older Korean

Figure 2. Four Latent Classes among Old Males (41 years of age or older)



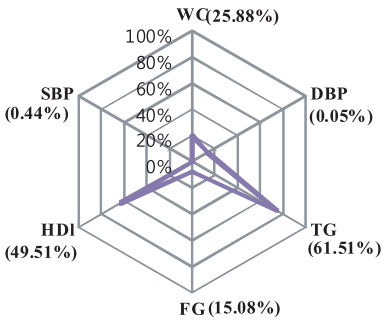
Healthy class

27.6% of Less Educated belong to healthy class[a]
20.5% of Highly Educated belong to healthy class [b]



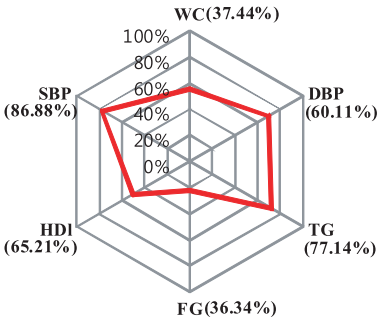
Blood Pressure only class

13.0% of Less Educated belong to Blood Pressure only class
32.23% of Highly Educated belong to Blood Pressure only class



Lipid only class

20.2% of Less Educated belong to Lipid only class
31.3% of Highly Educated belong to Lipid only class



Risky class

39.1% of Less Educated belong to Risky class
16.2% of Highly Educated belong to Risky class

Notes | WC = waist circumference, SBP = systolic blood pressure, HDL = HDL-cholesterol, FG = fasting glucose, TG = triglyceride, DBP = diastolic blood pressure.

[a] Less educated: person without bachelor's degree

[b] Highly educated: person with bachelor's degree or high

Each hexagon summarizes the proportion of people in each class who developed a risky level in each of the six metabolic syndrome risk factors. The distance from the origin shows the proportion of people who developed a risky level for each component.

men made up a different proportion of each class depending on their educational levels. Interestingly, we found that although highly educated men with a bachelor's degree made up a much lower proportion of the risky class (39% among highly educated male vs. 16% among less educated male), they composed a higher proportion of the blood-pressure-only and lipid-only classes. This reveals that although highly educated older men are much less likely to develop risky components of metabolic syndrome in general, they made up higher proportions of classes that had specific risks with compared to less educated male: 32% vs. 13% for the blood-pressure-only class and 31% vs. 20% for the lipid-only class, respectively.

Table 3. Latent Class Analyses of Metabolic Syndrome among Young Females

Exploratory Latent Class Analysis	L^2	G^2	DF	*p*-value
Two-class model	75.25	96.35	50	0.0001
Three-class model	39.16	52.72	43	0.1724
Four-class model[a]	20.22	19.62	36	0.9972
Five-class model	15.24	14.06	29	0.9990
Six-class model	12.47	11.27	22	0.9966
Confirmatory Latent Class Analysis[b]	**L^2**	**G^2**	**DF**	***p*-value**
M1: The proportions of four classes are different.	47.18	55.12	72	0.966
M2: The proportions of four classes except the "healthy" class are different.	47.26	55.06	73	0.972
M3: The proportions of four classes except the "blood pressure only" class are different.	48.57	57.19	73	0.969
M4: The proportions of four classes except the "lipid only" class are different.	47.31	56.85	73	0.972
M5: The proportions of four classes except the "risky" class are different.	47.32	55.22	73	0.981
M6: The proportions of four classes are identical[a].	48.61	57.13	75	0.980
Simultaneous Latent Class Analysisc	**L^2**	**G^2**	**DF**	***p*-value**
M6+ if the configurations of risk components in four classes are different.	47.29	49.44	75	0.996
M6+ if the configurations of risk components in four classes, except the "healthy" class, are different.	55.39	59.33	81	0.990
M6+ if the configurations of risk components in four classes, except the "blood pressure only" class, are different.	47.95	52.35	81	0.998
M6+ if the configurations of risk components in four classes, except the "blood pressure and lipid only" class, are different.	51.56	59.18	81	0.988
M6+ if the configurations of risk components in four classes, except the "risky" class, are different.	52.84	59.90	81	0.986
M6+ if the configurations of risk components in four classes are identical a.	67.57	75.14	99	0.982
Final Best Model: M6+ if the configurations of risk components in four classes are identical				

Notes | L^2 = likelihood ratio, X^2 = Pearson's X^2, DF=degrees of freedom

[a] Best Model in each analysis.

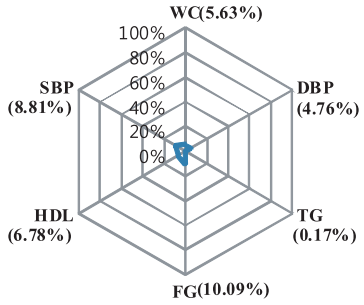
[b] A statistical test if the proportions of classes are identical between less-educated and highly educated.

[c] Once we assume the proportions of all classes are identical, we determine whether the configurations of risk components in each class are identical between the less-educated and the highly educated.

Young Females

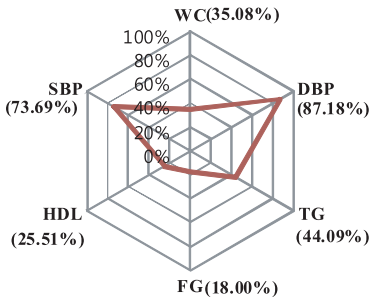
Table 3 reveals that four latent classes of metabolic syndrome also exist among young Korean women. Just like young Korean males, young Korean females did not show any difference between educational levels both in the proportion of each class and in the configuration of risk components in each class. Both educational groups shared four latent classes: the healthy class, the blood-pressure-only class, the lipid-only class, and the risky class. Although the characteristics of each class for females were quite similar to their young male counterparts,

Figure 3. Four Latent Classes among Young Females (40 years of age or younger)



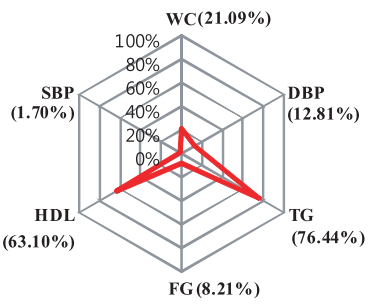
Healthy class

37.1% of Less Educated belong to healthy class[a]
37.1% of Highly Educated belong to healthy class [b]



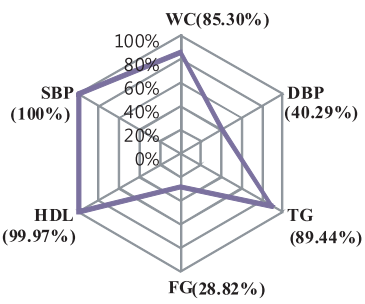
Blood Pressure only class

20.9% of Less Educated belong to Blood Pressure only class
20.9% of Highly Educated belong to Blood Pressure only class



Lipid only class

37.0% of Less Educated belong to Lipid only class
37.0% of Highly Educated belong to Lipid only class



Risky class

4.2% of Less Educated belong to Risky class
4.2% of Highly Educated belong to Risky class

Notes | WC = waist circumference, SBP = systolic blood pressure, HDL = HDL-cholesterol, FG = fasting glucose, TG = triglyceride, DBP = diastolic blood pressure.

[a] Less educated: person without bachelor's degree

[b] Highly educated: person with bachelor's degree or high

Each hexagon summarizes the proportion of people in each class who developed a risky level in each of the six metabolic syndrome risk factors. The distance from the origin shows the proportion of people who developed a risky level for each component.

the proportion of each class was quite different. Each class constituted 37%, 21%, 37%, and 4.2% of the young Korean female population, respectively. It is especially noteworthy that only 4.2% of young Korean women belonged to the risky class while 19.5% of young Korean men fell into the same class. In short, higher education did not have any protective effect on the development of metabolic syndrome among young Korean women. However, young Korean males made up a much lower proportion of the risky class that went on to develop most of the risk components of metabolic syndrome.

Old Females

Table 4. Latent Class Analyses of Metabolic Syndrome among Old Females

Exploratory Latent Class Analysis	L^2	G^2	DF	*p*-value
Two-class model	81.43	80.48	50	0.00
Three-class model	51.83	49.49	43	0.23
Four-class model[a]	39.44	38.66	36	0.44
Five-class model	31.55	36.49	29	0.27
Six-class model	30.95	35.85	22	0.12
Confirmatory Latent Class Analysis[b]	**L^2**	**G^2**	**DF**	***p*-value**
M1: The proportions of four classes are different.	59.36	59.98	72	0.945
M2: The proportions of four classes except the "healthy" class are different.	66.72	69.95	73	0.781
M3: The proportions of four classes except the "blood pressure only" class are different[a]	59.63	60.75	73	0.962
M4: The proportions of four classes except the "blood pressure and lipid only" class are different.	60.11	62.92	73	0.942
M5: The proportions of four classes except the "very risky" and the "lipid and obesity" classes are different.	59.52	62.13	73	0.941
M6: The proportions of four classes are identical.	66.21	69.02	75	0.846
Simultaneous Latent Class Analysis[c]	**L^2**	**G^2**	**DF**	***p*-value**
M3+ if the configurations of risk components in four classes are different[a].	58.60	49.44	75	0.957
M3+ if the configurations of risk components in four classes, except the "healthy" class, are different.	70.03	59.33	81	0.941
M3+ if the configurations of risk components in four classes, except the "blood pressure only" class, are different.	69.82	52.35	81	0.919
M3+ if the configurations of risk components in four classes, except the "lipid only" class, are different.	69.31	59.18	81	0.920
M3+ if the configurations of risk components in four classes, except the "risky" class, are different.	70.67	59.90	81	0.925
M3+ if the configurations of risk components in four classes are identical.	106.63	75.14	99	0.407
Final Best Model: M3+ if the configurations of risk components in four classes are different				

Notes | L^2 = likelihood ratio, X^2 = Pearson's X^2, DF = degrees of freedom

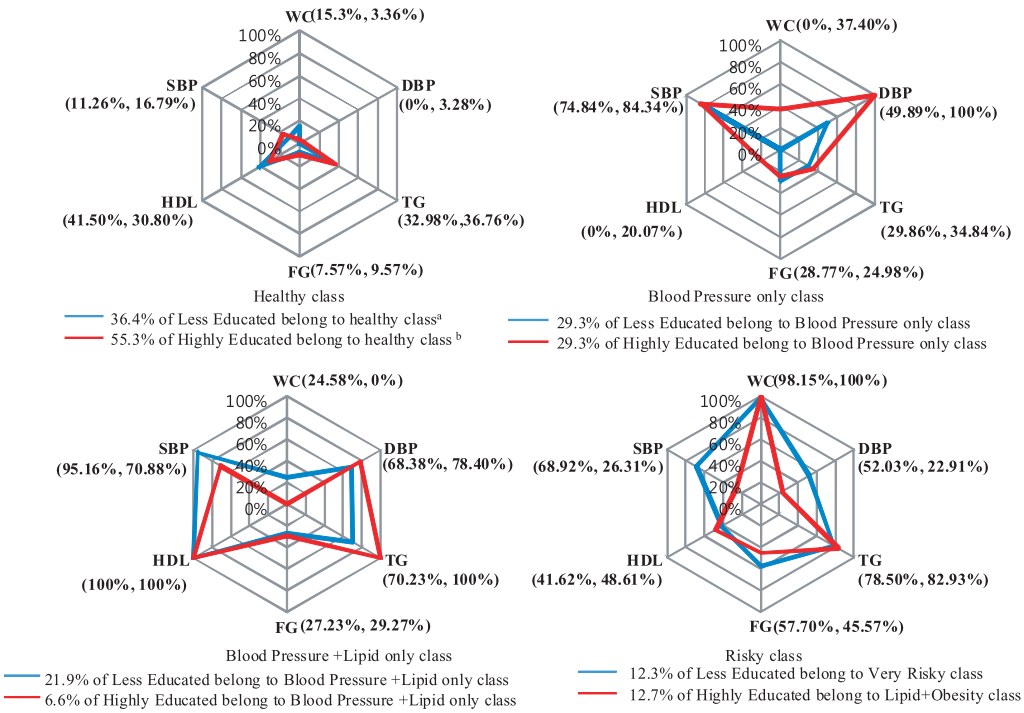
[a] Best Model in each analysis.

[b] A statistical test if the proportions of classes are identical between less-educated and highly educated.

[c] A statistical test if the configurations of risk components in each class are identical between the less-educated and the highly educated.

Table 4 summarizes the results of latent class analyses for Korean women who were 41 years of age or older. For the first time in this study, educational differences changed the configuration of each class, although the four-class model is still the best. Additionally, the proportion of each class, except the blood-pressure-only group, was different depending on educational level. We identified four latent classes, and a new class also emerged: a healthy class, a blood-pressure-only class, a blood pressure and lipid class, and a risky class. The health

Figure 4. Four Latent Classes among Old Females (41 years of age or older)



Notes | WC = waist circumference, SBP = systolic blood pressure, HDL = HDL-cholesterol, FG = fasting glucose, TG = triglyceride, DBP = diastolic blood pressure.

[a] Less educated: person without bachelor's degree

[b] Highly educated: person with bachelor's degree or high

Each hexagon summarizes the proportion of people in each class who developed a risky level in each of the six metabolic syndrome risk factors. The distance from the origin shows the proportion of people who developed a risky level for each component.

class, showed virtually no difference in the configuration of risk components, but there was a big difference in the proportion: only 36% of less-educated old Korean females were in this class, while more than half (55%) of the highly educated old Korean females belonged to this class. The opposite was the case for the blood-pressure-only class. There was no educational difference in the proportion of the classes: 29% of the less-educated and highly educated older female population belonged to this class. However, while all of the highly educated old women had abnormal diastolic blood pressures in this class, only half of the less-educated women in this class showed an abnormal level. Both the less-educated and the highly educated old women in the blood pressure and lipid class shared a similar configuration of risk components; they developed risky levels of both blood pressure and lipid factors. However, only 6.6% of highly educated old Korean women belonged to this class, while 22% of less-educated old

Korean women were included. The risky class exhibited a risky level for most metabolic risk components, and their proportion in the population was very similar in both educational groups (about 12%). The only difference between the educational groups was that less-educated women made up a higher proportion of the people who developed a risky level of blood pressure. In general, old Korean women developed the most complicated pattern of classes depending on educational level. The biggest difference was that highly educated women made up a higher proportion of the healthy class (55% vs. 36%), while they had a much lower prevalence in the blood pressure and lipid class (6.6% vs. 22%).

DISCUSSION

A series of factor analyses of metabolic syndrome revealed a set of risk components that constitutes metabolic syndrome (Gray et al. 1998; Li et al. 2007; Meigs et al. 1997; Novak et al. 2003). This study aimed to identify mutually exclusive groups in the population with regard to risk components of metabolic syndrome using a series of latent class analyses. Once factor analyses have successfully identified the underlying relationship between the risk components of metabolic syndrome, it would be necessary and important to determine what kind of subgroups exists within the population. This kind of research could provide richer information for the purpose of education and prevention by investigating who is at risk in terms of specific configurations of risk components, rather than by identifying simply who is affected or not by metabolic syndrome. For example, figure 4 revealed that about 12.7% of highly educated old female developed 'lipid + obesity' syndrome. They were not infected by metabolic syndrome yet and thus would be largely ignored by previous studies but our study identified them as a distinctive group who developed lipid and obesity risk components together and thus, were relatively easy to fell into metabolic syndrome. This kind of information has critical implications for establishing preventive strategies.

Latent class analysis, however, has some limitations when compared to factor analysis. First, the validity of the results of latent class analysis is partly dependent on the variables we choose for the analysis from the outset. In this sense, latent class analysis is a complement to factor analysis. Once factor analysis reveals essential dimensions (or components) of metabolic syndrome, latent class analysis can identify subgroups of the population with regard to those dimensions. In addition, since latent class analysis is for discrete variables, we cannot apply it to continuous variables. This is why we have to dichotomize each risk component in the beginning of our analysis. However, this limitation comes with one definite advantage: a built-in goodness-of-fit test. Each latent class model can be tested to see if it actually fits the data through a standard X^2 test. Furthermore, since the difference of goodness-of-fit of models also follows a X^2 distribution, we can compare models and choose the best-fitting model.

By using a series of three latent class analyses, several important facts were revealed about the Korean adult population. Based on the well-known fact that the prevalence of metabolic syndrome is quite distinctive depending on age and sex (Onat et al. 2003; Park et al. 2004), we drew our conclusions based on the four subpopulations of young males, old males, young females, and old females. Among both young and old men, four distinctive classes were identified: "healthy," "blood-pressure-only," "lipid-only," and "risky." No difference was found between different educational groups among males who were younger than 41. However, among men 41 years or older, those who did not have high school diploma made up a much higher proportion of the risky class when compared to the highly educated males (39% vs. 16%). Women were divided into four similar classes. Among the women who were 40 years of age or younger, there was no discrepancy across different educational groups. However, among women who were 41 or older, less-educated people composed a smaller proportion of the healthy class (36% vs. 51%) and also developed a new class: "very risky" (12%).

Education was proved to be a critical factor to develop metabolic syndrome especially among old population. Although the exact mechanisms are not known yet, it is well know that people with higher education are healthier than others maybe because they have advantages in gathering facts, learning concepts, and finding out how to access information and also they are more likely to have better housing, neighborhood and working conditions (Lynch and Kaplan. 2000). Metabolic syndrome is not an exception. For example, Björntorp argued that unfavorable socioeconomic circumstances coupled with psychosocial stress may lead to a physiological defeat reaction, thereby activating the hypothalamus-pituitary adrenocortical (HPA) axis as indicated by elevation of the major components of the metabolic syndrome, such as the waist to hip ratio (Björntorp 1991; Björntorp 1996). McEwen has also argued that allostatic load is the accumulated burden of lifelong stress resulting from the bodily responses to chronic overload or under-load, and that these adaptations leave their mark on human biological and physical functioning. Both low socioeconomic position and work stress were associated with atherogenic lipid pro file and hemostatic dysfunction (McEwen 1998).

Our results could be also useful for prevention at a population level. We identified not only a group of the population who were affected with metabolic syndrome, but also other groups of the population who exhibited some specific risk components of metabolic syndrome. For example, high blood-pressure itself has been known as closely related to cardiovascular diseases (Franklin et al. 1997; Gress et al. 2000; Sowers 1998; Sowers et al. 2001; Vasan et al. 2001) and also high levels of triglyceride that is directly related to lipid-only group also could lead to coronary diseases (Austin et al. 1998; Hwang et al. 1999; Hokanson and Austin 1996; Jacobs et al. 1990; Manninen et al. 1992; Nordestgaard et al. 2007). Also as they are getting old, it is relatively easy for them to be infected by additional risk components and thus to be fallen to metabolic syndrome. Therefore preventive efforts must pay special attention to

'blood-pressure only' and 'lipid-only' group members in addition to the people who have already developed metabolic syndrome.

This study also poses one interesting theme for future study. It is evident that education discrepancies make a difference only later in life, and our results implied a hypothesis of a cumulative disadvantage in South Korea: there is an increasing heterogeneity and inequality within aging cohorts that epidemiologists, sociologists and psychologists alike have noted (Ferraro and Kelley-Moore 2003; Ross et al. 1996). Some studies also showed that socioeconomic positions in childhood have lasting effects on the distribution of risk components of metabolic syndrome in adult life (Ebrahim et al. 2004; Golden et al. 2002). Future studies might focus on identifying and revealing the mechanisms of this cumulative disadvantage; it could result from either a simple cumulative discrepancy over the lifetime, or a differential institutional effect such as pension, retirement, etc.

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