Progress in Nutrition 2018; Vol. 20, N. 4: 602-615 DOI: 10.23751/pn.v20i4.7274 © Mattioli 1885

Original article

Socioeconomic, dietary, nutrition, body weight and epidemiologic transitions: three nations at different stage of development

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Summary. *Objectives:* The present study examined how socio-economic changes has associated with changes of dietary, nutritional, physical activity, body weight and diseases based on the systems of transition. This study empirically examined the system of transitions using data from three nations (Indonesia, Korea, and the US) at different stage of development. This study expanded the previous study by 1) replicating with more recent data, 2) including three nations for comparison, and 3) including diseases as a variable in addition to the other transitions. *Methods:* Indicators of socio-economic (GDP and urban population percentage), dietary (consumption of rice, sugar & sweeteners, vegetable oil, animal fat, milk, and meat), nutrition (consumption of energy, protein and fat), physical activity (proportion of population engaged in different employment sectors), body weight (overweight and obesity percentages), and epidemiological (communicable and non-communicable disease rates) transitions were collected from international open sources: the World Bank, FAO databank, WHO Global Health Observatory data repository, and from a publication issued by National Statistics Bureaus. Eight different years starting from 1980 to 2015, with a five-year interval between years, were examined. Spearman's rank correlation and path analysis was conducted using SPSS and SAS. *Results:* While GDP increased in all three nations, proportion of urban population significantly increased only in Indonesia. Regarding dietary transition, only vegetable oil consumption significantly increased in all three nations, but no particular significant trends were found in nutrition transition. All three nation showed significant decrease in percentage of the population employed in agriculture and significant increase in percentage of the population in service sector. Body weight transition was significantly occurred in all three nations. Only fasting glucose level significantly increased in all three nations, while high blood pressure and total blood cholesterol level fluctuated over the study period and by sex. The model of the system of transitions showed that epidemiological transition was highly related to body weight transition, which, in turn, significantly affected by physical activity and dietary transition. *Conclusions:* This study found that the three nations at different stage of development showed different level in each transition and that the transitions were interrelated as shown in the system of transitions. This systematic view would be helpful to find ways to solve current nutrition and health problems.

Key words: Nutrition transition, Dietary transition, Body Weight transition, Epidemiologic transition, Indonesia

Introduction

Recent years have witnessed notable changes in many areas of life, such as changes in foods we eat and changes in body weight. While the notable changes have been carefully documented, attempts have also been made to understand the changes in more systematic and inter-connected ways (1,2). The term of transition has been used to describe changes over time in various fields such as nutrition and epidemiology. Figure 1 illustrates how various transitions including nutrition transition are related together as a system.

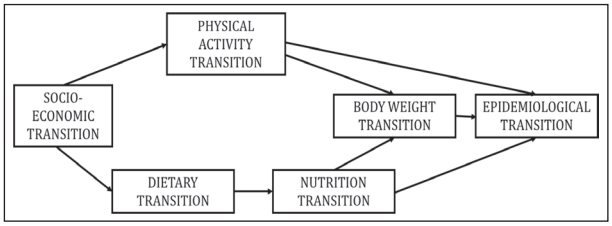


Figure 1. The system of Transitions (modified from Lee & Sobal, 2003)

Socio-economic transition indicates changes at the macro level, and is believed to be associated with globalization, urbanization, and industrialization (1). Better economic situations allow individuals to learn and live in safer and more affluent environments, and higher education levels are one of effects of this transition (3,4).

Dietary transition describes changes in dietary pattern from a more plant-based, fiber rich traditional diet to a westernized diet high in sugar, animal-based, and processed food but low in fiber, and this transition is believed to be associated with income, globalization and westernization. The spread of fast food restaurants and supermarkets is a characteristic of dietary transition, which leads to changes in nutrient consumption profiles, namely nutrition transition (5-7). In general, nutrition transition progresses to higher consumptions of fat, protein, and simple carbohydrates and lower fiber consumption.

Physical activity transition occurs as a result of the development of economy and technology, due to movement away from the agriculture sector, which requires high energy expenditure, to industrial or service sectors (8,9). The developments in public transportation and household appliances also affect how people move, live, and spend their leisure time. All of these changes lead toward a sedentary way of life and less energy expenditure.

Body weight transition describes changes of body weight over time. Socio-economic situation, dietary and nutrient intake, and physical activity transitions also causes body weight transition toward obesity (1,2,10), which used to be an issue in high-income countries, but is now rapidly becoming of concern in developing countries, particularly in low socio-economic groups (11).

Epidemiological transition was first termed by Omran (12), and is generally defined as a change from high mortality at a younger age due to infectious disease to low mortality related to non-communicable diseases (NCD) at an older age. Unhealthy diets, exposure to alcohol and tobacco, and physical inactivity have been cited as risk factors of non-communicable diseases (13).

As illustrated in Fig. 1 (1), socio-economic transition influences dietary transition which in turn is related to nutrition transition. Physical activity transition is also affected by socio-economic transition, and nutrition and physical activity transitions lead to body weight transition, and finally, to epidemiological transition. Epidemiological transition could be also directly affected by nutrition and physical activity transition.

Another way to comprehensively understand various changes, in addition to the system of transitions, is Popkin's five nutrition patterns (14). Popkin described the various changes in dietary and nutrient consumption, which he referred to as "nutrition transition", and divided human food consumption experiences over time into five nutrition patterns by mode of food production, type of diet, and nutrient consumption. Although the patterns are named as nutrition patterns, they incorporate demographic and epidemiological aspects in addition to diet and nutrition. The five nutrition patterns (14) include "collecting food," "famine," "receding famine," "nutrition-related noncommunicable disease," and "behavioral change." The "collecting food" pattern is of hunter-gatherer society. The "famine" pattern is probably the longest pattern in human history. Many societies have moved on to "receding famine" where more fruits, vegetables, and animal protein were available. Most high-income societies seem to simultaneously have both "nutrition-related noncommunicable disease" and "behavioral change" pattern. "Nutrition-related noncommunicable disease" pattern indicates increasing noncommunicable diseases stemmed from unhealthy diet and no physical activity. "Behavioral change" pattern is reaction to "nutrition-related noncommunicable disease" pattern to obtain better health through healthy diet and active lifestyle. These patterns are generally on the time continuum, however, different nations could be in different pattern at the same time.

The aim of the present study was to examine socio-economic, dietary, nutrition, physical activity, body weight and epidemiological transitions in three

nations at different stages of development, using the work of Lee & Sobal (1) and Popkin (14) as guides. This study empirically examined the system of transitions (1) using data from three nations and attempted to locate the nations in the five nutrition patterns (14). This study attempted to expand the previous studies by 1) replicating with more recent data, 2) including three (a developing, a developed, and a most developed) nations for comparison, and 3) including diseases as a variable in addition to the other transitions.

Subject and methods

Three Nations and Data Sources

The three nations studied were Indonesia (a developing country), South Korea (a developed country), and the US (a most developed country). Indonesia is the fourth most populated country in the world and is categorized as lower-middle income country by the World Bank. In Indonesia, the double burden of malnutrition is found in all income and population levels. Furthermore, although it struggles to overcome underweight problem, the rate of overweight is also rising (15). As a developing country, it is inevitable that many transitions, especially those affecting health will occur among Indonesians. South Korea is a country with high-income economics by World Bank (16) and joined the OECD (Organization for Economic Cooperation and Development) in 1996 (17). This would indicate South Korea is recognized as developed country. South Korea is the first country that became a donor country from a recipient country (18). Transitions in South Korea have been reported with a focus on nutrition transitions (1, 19). The US was included as a most developed country.

Eight different years starting from 1980 to 2015, with a five-year interval between years, were chosen of the study spanning 35 years. The selection was necessary because Indonesian nutrition transition data was available from 1980 in five-year interval. Because of the different sources, data were sometimes taken from closest years from the preselected years.

This study used open data sources in public domain. Socioeconomic and physical activity transition data was obtained from World Bank Database (20). Dietary transition data was drawn from the FAO Food Balance Sheet (21). WHO Global Health Observatory data repository (22) provided data for epidemiological and body weight transition. Nutrition transition data for Indonesia, South Korea, and the US was obtained from a 'Statistics of 70th Indonesia Independence' a publication of the National Statistical Bureau of Indonesia (23), the Korea National Health and Nutrition Examination Survey (KNHANES) (24), and the National Health and Nutrition Examination Survey (NHANES) (25), respectively.

Variables

Socio-economic transition was examined using Gross Domestic Product (GDP) and percentage of the population residing in an urban environment (urbanization). GDP was used to assess economic development and domestic production levels. Both indicators were obtained from the World Bank databank (20).

Dietary transition was mostly examined using proportions of foods consumed or frequencies of consumptions of foods. FAO Food Balance Sheet data (21) on food consumption per capita was obtained to observe trends. The several food items investigated in this study, that is, rice, sugar and sweeteners, vegetable oil, animal fat, milk, and meat, were chosen because they are usually most involved in dietary transition (1,2).

Studies on nutrition transition are somewhat limited. Indonesian carbohydrate, protein, and fat intake data are not generally available to the public. Information was obtained from "Statistics of 70th Indonesia Independence (23)," which contained data on calorie (kcal/capita/day), protein (gram/capita/day), and fat (gram/capita/day) consumption. This data was available from 1984 but only available annually from 2003, a six years interval was chosen from 1984 to best match the timings of other transition indicators. Fat consumption data was only available for 2002, 2008, and 2014.

Physical activity transition data was obtained from employment sector information obtained from the World Bank databank (20). The agriculture sector was considered as the sector requiring most physical energy, followed in decreasing order by the industrial and service sectors.

Percentages of overweight (BMI≥25) and obese (BMI≥30) males and females aged ≥ 18 years obtained from the WHO Global Health Observatory data repository were utilized to examine body weight transition. According to WHO, BMI is the metric most used to estimate the prevalence of underweight and overweight in populations (26).

Epidemiological transition was assessed using the incidences of non-communicable and communicable diseases (12, 14). Tuberculosis (TB) was used as a representative of communicable disease, but unfortunately, the prevalence of TB was only available from 1990. Non-communicable diseases were assessed using proportions with high blood pressure (systole ≥ 140 mmHg or diastole ≥ 90 mmHg), high fasting blood glucose (≥7.0mmol/L) for males and females aged ≥ 18 years, and mean total blood cholesterol (in mmol/L) of males and females aged ≥ 25 years. The data were extracted from the WHO Global Health Observatory data repository (22).

Although this study tried to match variables used in the previous system of transition study as closely as possible (1), some changes were inevitable for mostly availability issue. This study used GDP in place of GNP (Gross National Product) used in the previous study (1) because GDP is a more widely used indicator for health of national economy. The education variable in socioeconomic transition (percentage of high school graduate) was dropped because of non-availability. Dietary transition variables in this study also differed to draw the data from the same data source. Nutrition transition variables in this study were amount of consumption rather than proportions of total energy from macronutrients used in the previous study. This change was also made to maintain the similarity across the three nations. Body weight transition variables in this study are better indicators (prevalence of overweight and obesity) than the average BMI of 17-year olds used in this previous study.

Analysis

Descriptive and statistical analyses were conducted to observe trends over time for the selected transition indicators. P-values and correlation coefficients of indicators were calculated using Spearman's rank correlation analysis in IBM SPSS ver 22.0 (SPSS Inc., IBM corp., NY, USA). Figures were also drawn for graphic presentation.

The model of system of transitions (Fig. 1) was examined with path analysis using the CALIS procedure in SAS software ver 9.4 (SAS Institute, Inc., Cary, North Carolina, USA). Body weight and epidemiological transition data for each sex were available, therefore separate path models for men and women were constructed. Each transition was represented by one variables. For socioeconomic transition, GDP was used because this variable showed changes over the entire period. Dietary transition was represented by oil consumption that was the only variable showed significant trend in all three nations. In line with oil consumption, fat consumption would be a good choice for nutrition transition, however, fat consumption for Indonesia from 1984 to 1996 were not available. Both energy and protein consumption were attempted. Physical activity transition was represented by percentage of people engaged in agriculture transition. Body weight transition was represented by proportion of overweight (BMI ≥ 25). For epidemiological transition, proportion of high fasting blood glucose was chosen because only this variable showed significant changes over time in all three nations. Standardized coefficients and residuals were used to show relationships among transitions. Model fit in the CALIS procedure was considered with absolute index (P value for chi-square), Parsimony index (RMSEA estimate), and incremental fit index (CFI and NFI) (27). Insignificance of chi-square indicates the model cannot be rejected. RMSEA estimates less than 0.05 are generally considered good. The greater value of CFI and NFI are considered better and, in general, values over 0.9 are considered good.

Results

Socio-economic transition

The Gross Domestic Products (GDP) of Indonesia, Korea, and US steadily increased over the study period (Fig. 2 (a)). Although Indonesia's GDP was below that of Korea or the US, all three countries showed statistically significant growth over time ($P<0.001$). Urban population percentages showed similar increases (Fig. 2 (b)). In 1980, Indonesia had an urban popula-

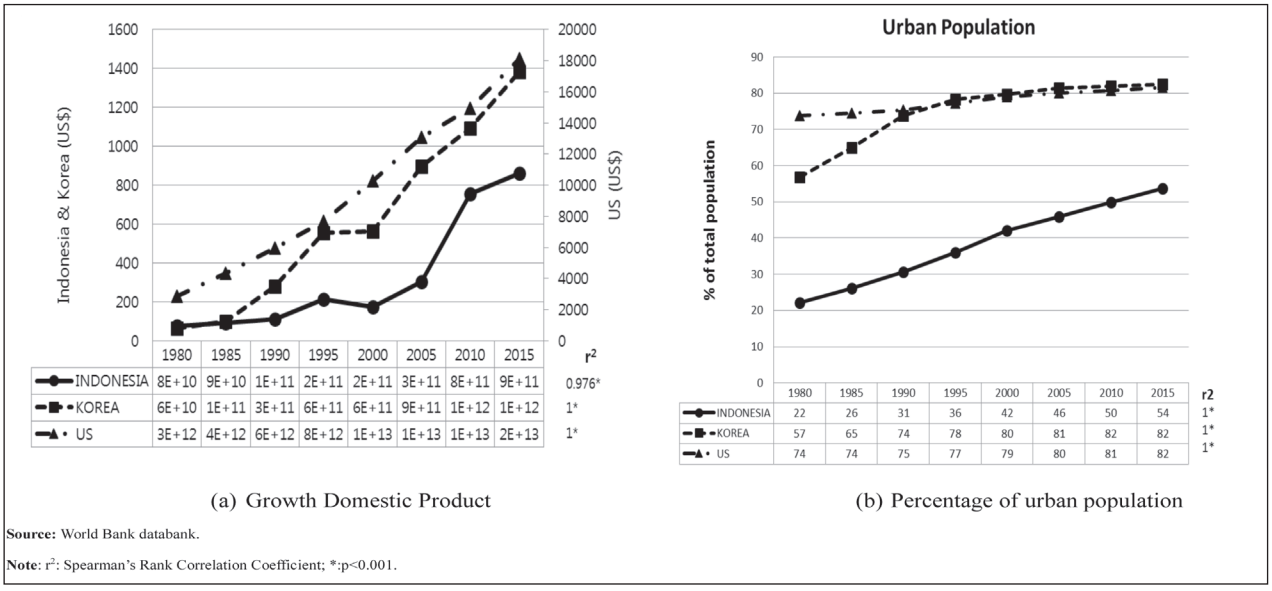


Figure 2. Socio-economic transition in Indonesia, Korea, and the US

tion percentage of 22%, but in 2015 this percentage was almost 2.5 times higher. On the other hand, Korea and the US had much higher urban population percentages. In 2015, it was over 80% in both countries. Furthermore, the increases in urban population percentages in all three nations were statistically significant ($p<0.001$).

Dietary transition

Consumptions of the six food items selected from the FAO Food Balance Sheet in Indonesia, Korea, and US were varied (Table 1). Rice is the staple food in Indonesia and Korea, but unlike that observed in Korea in which rice consumption significantly decreased over the study period ($p<0.05$), rice consumption in Indonesia did not change. The consumption of sugar and sweetener in Indonesia was steady, whereas sugar and sweetener consumption in Korea increased significantly over the study period ($p<0.05$). Although sugar and sweetener consumption in the US did not significantly increased over the study period, the consumption level was higher than that in Indonesia and Korea. In 2013, sugar and sweetener consumption in the US was almost four times that in Indonesia and more than 1.5 times that in Korea. Vegetable oil consumption was the only food item that significantly increased in all three nations, Indonesia ($p<0.05$), Korea ($p<0.001$), and the US ($p<0.001$). As for animal fat consumption, consumption in Indonesia remained constant over the study period, whereas it increased significantly in Korea ($p<0.05$). Milk consumption in Indonesia and Korea increased significantly from 1980. In Indonesia, milk consumption more than doubled between 1980 and 2013 ($p<0.05$). Of the six food items included in the study, meat consumption showed the largest increase in Indonesia by three-fold between 1980 and 2013 ($p<0.001$). Korea's meat consumption increase was even higher by six-fold during the study period ($p<0.001$), but meat consumption in the US did not show significant change and started to decline since 2010.

Nutrition transition

Shifts in the consumptions of energy, protein, and fat between 1984 and 2014 are summarized in Table 2. Energy consumptions in Indonesia, Korea, and the US fluctuated over time, and no country exhibited a meaningful trend. Protein consumption in Indonesia non-significantly increased, and greatest protein consumption occurred in 2008 at 58 gram/capita/day. Protein consumptions in the US and Korea were higher than in Indonesia but varied with time. Data on fat consumption in Indonesia was only available for 2002, 2008, and 2014, and the highest value reached was 47 gram/capita/day in 2008. The consumption of fat in Korea was significantly increasing from 24 gram/capita/day in 1984 to 48 gram/capita/day in 2014 ($p<0.05$).

Table 1. Dietary Transition – Consumption of selected food items in Indonesia, Korea, and the US

	Year									
Country & Indicators	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2013**	**p-value[1]**	**r[2]**
INDONESIA										
Rice (kg/capita/year)	125	141	131	131	130	125	132	135	0.531	0.262
Sugar & sweeteners (kg/capita/year)	14	14	14	16	16	17	14	17	0.102	0.619
Vegetable oil (kg/capita/year)	6	8	7	7	8	9	10	10	**0.011***	0.826
Animal fat (kg/capita/year)	0.3	0.4	0.5	0.5	0.4	0.4	0.5	0.5	0.233	0.476
Milk (kg/capita/year)	7	6	4	8	8	9	13	15	**0.002****	0.905
Meat (kg/capita/year)	5	6	8	10	8	10	12	14	**<0.001*****	0.976
KOREA										
Rice (kg/capita/year)	138	120	97	96	88	76	84	85	**0.005****	-0.871
Sugar & sweeteners (kg/capita/year)	16	21	32	32	35	38	38	38	**0.002****	0.910
Vegetable oil (kg/capita/year)	3	6	9	9	13	15	18	18	**<0.001*****	0.986
Animal fat (kg/capita/year)	2	3	2	3	3	3	3	3	**0.006****	0.859
Milk (kg/capita/year)	11	17	19	22	28	27	23	29	**0.004****	0.876
Meat (kg/capita/year)	13	18	25	39	48	50	59	64	**<0.001*****	0.990
US										
Rice (kg/capita/year)	4	3	7	8	7	7	7	7	0.083	0.647
Sugar & sweeteners (kg/capita/year)	57	59	63	67	69	70	61	64	0.220	0.488
Vegetable oil (kg/capita/year)	21	23	24	24	28	28	30	30	**<0.001*****	0.979
Animal fat (kg/capita/year)	7	7	5	5	6	6	5	5	0.128	-0.585
Milk (kg/capita/year)	238	256	257	260	257	258	252	255	0.179	-0.528
Meat (kg/capita/year)	104	110	113	118	122	125	119	115	0.053	0.700

Source: FAO Food Balance Sheet (Food Consumption).
Note: [1)]Spearman's Rank Correlation analysis; [2)]Correlation coefficient; *p-value<0.05; **p-value<0.01; ***p-value<0.001.

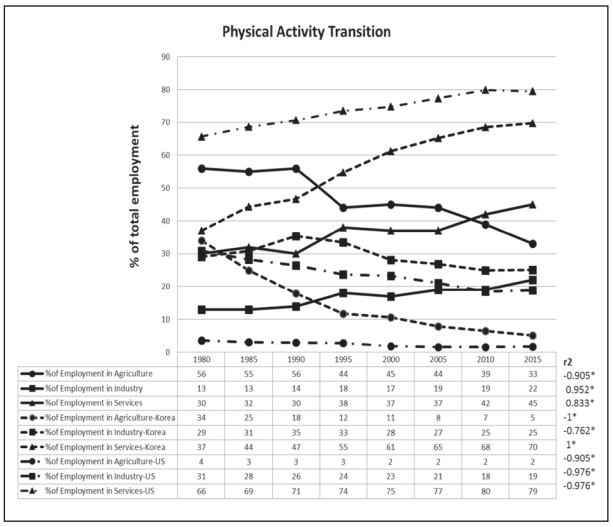
Table 2. Nutrition Transition – energy, protein, and fat consumptions in Indonesia, Korea, and the US

	Year							
Country & Indicators	**1984**	**1990**	**1996**	**2002**	**2008**	**2014**	**p-value[4]**	**r[5]**
INDONESIA[1]								
Consumption of energy (kcal/capita/day)	1798	1901	2020	1987	2038	1859	0.468	0.371
Consumption of protein (gram/capita/day)	43	45	55	55	58	54	0.173	0.638
Consumption of fat (gram/capita/day)	-	-	-	45	47	43	0.667	-0.500
KOREA[2]								
Consumption of energy (kcal/capita/day)	1901	1868	1931	2066	1868	2063	0.397	0.429
Consumption of protein (gram/capita/day)	69	79	73	74	67	72	0.623	-0.257
Consumption of fat (gram/capita/day)	24	29	41	45	39	48	**0.042***	0.829
US[3]								
Consumption of energy (kcal/capita/day)	2111	1839	2005	2178	2070	2079	0.707	0.143
Consumption of protein (gram/capita/day)	81	74	74	79	78	80	0.872	0.086
Consumption of fat (gram/capita/day)	87	72	74	81	78	80	0.957	-0.029

Source: [1)] Statistics of 70th Indonesia Independence; [2)] KNHANES; [3)] CSFII and NHANES.
Note: [4)]Spearman's Rank Correlation analysis; [5)]Correlation coefficient; *p-value<0.05; **p-value<0.01; ***p-value<0.001.

Physical activity transition

Trends in physical activity were assessed based on type of employment (Fig. 3). The percentage of the population employed in agriculture in Indonesia significantly decreased from 56% in 1980 to 34% in 2014, and similar movements were observed for Korea ($p<0.001$) and the US ($p<0.001$), whereas the percentage employed in the industrial and service sectors significantly increased ($p<0.001$ and $p<0.05$, respectively). On the other hand, Korea and the US employment in the industrial sector significantly decreased from 1980 to 2000s ($p<0.05$ and $p<0.001$, respectively). However, Indonesia, Korea, and the US showed similar significant increasing trends in the percentages employed in service sector ($p<0.05$, $p<0.001$, and $p<0.001$, respectively).



	1980	1985	1990	1995	2000	2005	2010	2015	r2
%of Employment in Agriculture	56	55	56	44	45	44	39	33	-0.905*
%of Employment in Industry	13	13	14	18	17	19	19	22	0.952*
%of Employment in Services	30	32	30	38	37	37	42	45	0.833*
%of Employment in Agriculture-Korea	34	25	18	12	11	8	7	5	-1*
%of Employment in Industry-Korea	29	31	35	33	28	27	25	25	-0.762*
%of Employment in Services-Korea	37	44	47	55	61	65	68	70	1*
%of Employment in Agriculture-US	4	3	3	3	2	2	2	2	-0.905*
%of Employment in Industry-US	31	28	26	24	23	21	18	19	-0.976*
%of Employment in Services-US	66	69	71	74	75	77	80	79	-0.976*

Figure 3. Physical Activity Transition – Percentage employment by sector in Indonesia, Korea, and the US
Source: World Bank databank.
Note: r2: Spearman's Rank Correlation Coefficient; *:p<0.001

Body weight transition

The percentages of overweight and obese men and women in Indonesia, Korea, and the US (Table 3) in-

Table 3. Body Weight Transition – Percentage of overweight and obese men and women in Indonesia, Korea and the US

	Year									
Country & Indicators	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**p-value[1]**	**r^2**
INDONESIA										
Overweight (%)										
Men	5	7	8	10	13	16	20	24	**<0.001*** **	1
Women	10	12	14	17	20	23	27	31	**<0.001*** **	1
Obesity (%)										
Men	0	0	1	1	1	2	3	5	**<0.001*** **	1
Women	1	1	2	3	4	5	7	9	**<0.001*** **	1
KOREA										
Overweight (%)										
Men	14	17	20	23	26	29	31	34	**<0.001*** **	1
Women	14	17	19	22	23	24	25	26	**<0.001*** **	1
Obesity (%)										
Men	0	1	1	2	2	3	4	4	**<0.001*** **	1
Women	1	2	2	3	3	4	4	5	**<0.001*** **	1
US										
Overweight (%)										
Men	49	52	56	60	64	67	70	72	**<0.001*** **	1
Women	40	43	46	50	54	57	60	64	**<0.001*** **	1
Obesity (%)										
Men	12	14	17	20	2	28	31	35	**<0.001*** **	1
Women	15	17	20	23	27	30	33	36	**<0.001*** **	1

Source: WHO Global Health Observatory data repository.
Note: [1)]Spearman's Rank Correlation analysis; [2)]Correlation coefficient; *p-value<0.05; **p-value<0.01; ***p-value<0.001; Overweight: BMI≥25; Obesity: BMI≥30.

creased significantly over the study period (p<0.001). In Indonesia, more women were both overweight and obese than men, whereas in Korea and the US, more women were overweight, but not obese, than men. The proportion of overweight Indonesian adults more than tripled between 1980 and 2015, and the proportion of obese adults increased profoundly by 10-fold.

Epidemiological transition

In Indonesia, the percentages of men and women with high blood pressure increased from 1980 to 2000 and subsequently decreased slightly (Table 4). Over the same period, percentages fell significantly in Korea and the US (p<0.001). Although values were only available for 2010 and 2015, percentages with a high fasting blood glucose levels significantly increased in all three countries (p<0.001). Mean total blood cholesterol increased significantly in Indonesian women from 1980 to 2010 (p<0.05), whereas in Indonesian men, mean total cholesterol levels non-significantly declined. Mean total cholesterol significantly decreased in the US men and women over the same period (p<0.001). While in Korean women it remained at 4.8 mmol/L.

TB was used as a surrogate of communicable disease. Over the study period, the prevalence of TB was much greater in Indonesia than in Korea or the US, but then decreased significantly from 2000 to 2015 (p<0.001). In 2000, the prevalence of TB was low in the US at 6 per 100,000/ year, and thereafter, significantly decreased.

System of transitions

Path models from CALIS procedure based on Fig. 1 were attempted, but the procedure could not be completed with basic assumption for CALIS procedure not met. Therefore, models without nutrition transition had to be attempted and shown in Figures 4 and 5. The models, however, appeared to have low goodness-of-fit. The model for Indonesian women (Fig. 4 (a)) showed good level of goodness-of-fitness based on p value (0.10) for chi-square test, CFI of 0.93, and NFI of 0.86, but RMSEA estimate larger than 0.05 indicated otherwise. Models for Korean women (Fig. 4 (b)) and the US women (Fig. 4 (c)) showed lower level of goodness-of-fit than the model for Indonesian women. P value for chi-square test and RMSEA estimate could not be computed for the US women model. All path coefficients in models for women were significant at p=0.05 with two exceptions: the coefficient (0.23) for the path from dietary transition to body weight transition in Indonesia model and the coefficient (-0.30) for the path from physical activity transition to body weight transition in the US model. Models for men also appeared to have low goodness-of-fitness. While the model for Indonesian men showed relatively good level of goodness-of-fitness with non-significant P value for chi-square test and CFI and NFI close to or over 0.9, although RMSEA estimate was larger than 0.05. Korea men model showed relatively poor goodness of fit with significant p value for chi-square test and large RMSEA estimate while CFI and NFI was close to 0.9. For the US men model, P value for chi-square test and RMSEA estimate could not be computed for the US men model, but CFI and NFI were over 0.9. For models for men, only one path coefficient from dietary transition to body weight transition in Korea model was not significant at p=0.05.

Relationships among transitions generally similar across nations. GDP had a strong influence on dietary transition (standardized path coefficients 0.89~0.97) and on physical activity transition (-0.88~-0.93). Influence from physical activity transition to body weight transition appeared higher than that from dietary transition to body weight transition given higher path coefficients from physical transition to body weight transition. Body weight transition was highly related with epidemiological transition with path coefficients close to one. No direct effects from physical activity and dietary transition to epidemiological transition were found.

Discussion

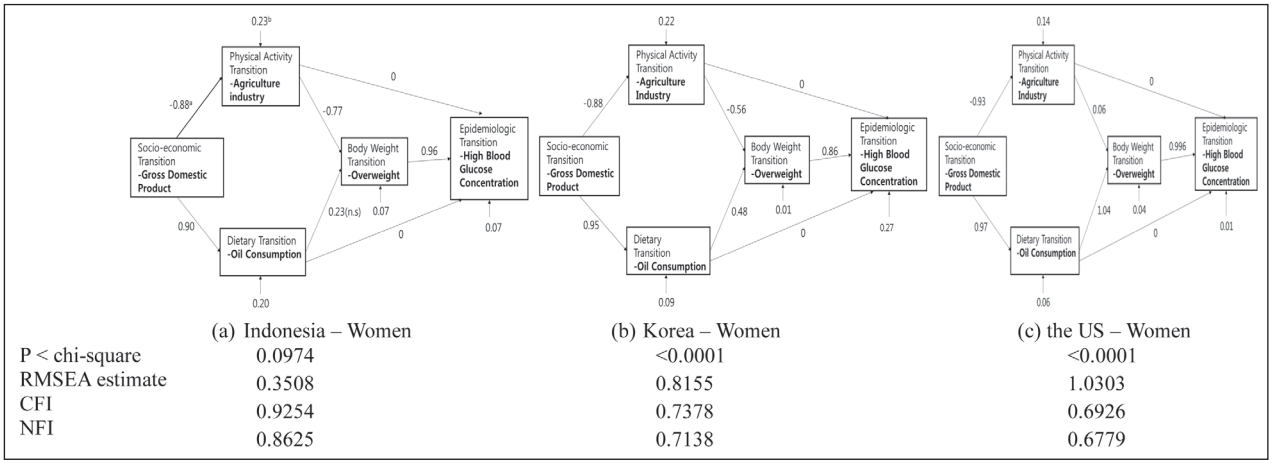
This study was conducted to document trends of socio-economic, dietary, nutrition, physical activity, body weight, and epidemiological transitions in three nations (Indonesia, Korea, and the US) at different development stage. The system of transitions was also examined. Socio-economic transition was marked

Table 4. Epidemiological Transition- Noncommunicable and communicable disease in Indonesia, Korea, and US

	Year									
Country & Indicators	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**p-value[1]**	**r[2]**
INDONESIA										
Noncommunicable disease										
High blood pressure (%)										
Men	23.6	24.2	24.7	25.2	25.5	25.5	25.0	24.3	0.217	0.491
Women	22.4	23.3	24.1	24.7	24.9	24.6	23.9	23.1	0.651	0.190
High fasting blood glucose (%)										
Men	3.2	3.7	4.3	5.0	5.8	6.5	7.0	7.4[4]	**<0.001*** **	1
Women	4.1	4.7	5.4	6.2	6.9	7.4	7.7	8.0[4]	**<0.001*** **	1
Mean total cholesterol (mmol/L)										
Men	4.6	4.5	4.5	4.5	4.5	4.5	4.5[5]	-	0.144	-0.612
Women	4.6	4.6	4.6	4.6	4.6	4.7	4.7[5]	-	**0.034***	0.791
Communicable disease										
TB prevalence (per 100,000)	-	-	443	485	452	348	283	272[5]	**<0.001*** **	-1
KOREA										
Noncommunicable disease										
High blood pressure (%)										
Men	21.1	19.6	18.3	16.4	14.3	12.7	10.4	8.2	**<0.001*** **	-1
Women	25.2	24.3	23.5	22.2	20.4	19.0	16.5	13.8	**<0.001*** **	-1
High fasting blood glucose (%)										
Men	4.0	5.2	6.6	7.6	8.2	8.1	8.6	9.3[4]	**<0.001*** **	0.976
Women	4.4	5.3	6.2	6.8	6.8	6.4	6.5	6.7[4]	0.091	0.635
Mean total cholesterol (mmol/L)										
Men	4.8	4.8	4.8	4.8	4.8	4.8	4.8[5]	-	-	-
Women	5	4.9	4.8	4.8	4.8	4.8	4.9[5]	-	0.350	-0.418
Communicable disease										
TB prevalence (per 100,000)	-	-	223	202	184	167	152	143[5]	0.600	0.600
US										
Noncommunicable disease										
High blood pressure (%)										
Men	19.5	17.1	15.3	14	13	12	11.2	10.5	**<0.001*** **	-1
Women	27	23.9	21.2	19	17.5	16.6	15.9	15.3	**<0.001*** **	-1
High fasting blood glucose (%)										
Men	4.7	5.1	5.7	6.4	7.0	7.5	7.9	8.2[4]	**<0.001*** **	1
Women	4.3	4.5	4.9	5.3	5.7	6.0	6.2	6.4[4]	**<0.001*** **	1
Mean total cholesterol (mmol/L)										
Men	5.6	5.5	5.5	5.4	5.3	5.2	5.0[5]	-	**<0.001*** **	-0.991
Women	5.7	5.6	5.5	5.4	5.3	5.2	5.1[5]	-	**<0.001*** **	-1
Communicable disease										
TB prevalence (per 100,000)	-	-	14	12	8	6.8	5.1	4.1[5]	**<0.001*** **	-1

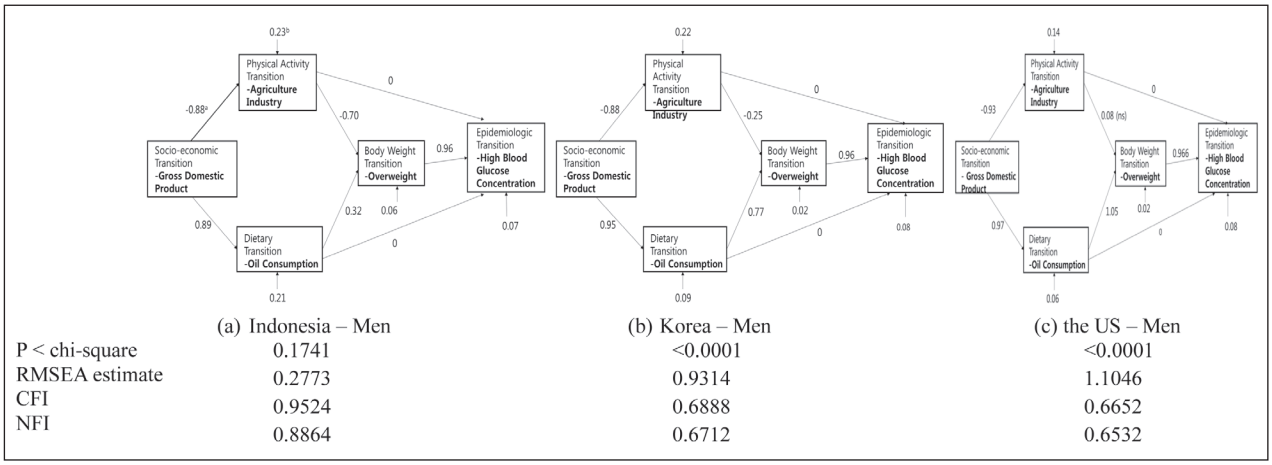
Source: WHO Global Health Observatory data repository.

Note: [1)]Spearman's Rank Correlation analysis; [2)]Correlation coefficient; [4)] Year 2014; [5)] Year 2009; *p-value<0.05; **p-value<0.001; ***p-value<0.001



	(a) Indonesia – Women	(b) Korea – Women	(c) the US – Women
P < chi-square	0.0974	<0.0001	<0.0001
RMSEA estimate	0.3508	0.8155	1.0303
CFI	0.9254	0.7378	0.6926
NFI	0.8625	0.7138	0.6779

Figure 4. A model of a system of transitions in Indonesia, Korea and the US women. a.Path coefficients; b. residuals



	(a) Indonesia – Men	(b) Korea – Men	(c) the US – Men
P < chi-square	0.1741	<0.0001	<0.0001
RMSEA estimate	0.2773	0.9314	1.1046
CFI	0.9524	0.6888	0.6652
NFI	0.8864	0.6712	0.6532

Figure 5. A model of a system of transitions in Indonesia, Korea and the US men. a. Path coefficients; b. residuals

with increasing GDP and urbanization level. While GDP increased in all three nations, proportion of urban population increased continuously only in Indonesia. Regarding dietary transition, this study found increasing trend of consumption. Particularly, vegetable oil consumption significantly increased in all three nations. Data on nutrition transition did not display any particular pattern in three nations. As for physical activity transition, all three nation showed significant decrease in percentage of the population employed in agriculture and significant increase in percentage of the population in service sector. But, significant increase in the industrial sector was found only in Indonesia. Body weight transition as increasing overweight and obesity was observed in all three nations. Epidemiological transition varied in each nation and each indicator. Only fasting glucose level significantly increased in all three nations, while high blood pressure and total blood cholesterol level fluctuated over the study period and by sex. Although the total model of the system of transition could not be structured, the partial model without nutrition transition was examined. The model was stronger in Indonesian data than Korean and the US data in terms of goodness of fit. The model showed that epidemiological transition was highly related to body weight transition, while no direct relationship of epidemiological transition with physical activity and dietary transition was found.

This study confirmed that transitions progress with development (1, 2, 8, 12). Urbanization was almost completed before 1980s in the US and by 1990 in Korea, while Indonesia showed growing urban population.

Dietary transition was particularly interesting. While the US showed only one food item (vegetable oil) in significantly increasing consumption pattern and Indonesia showed three food items (vegetable oil, milk, and meat), Korea showed significant trends in all six food items. Rice, a staple food of Korea, showed significant decrease, but all the rest significantly increased in consumption. Perhaps, active dietary transition may require certain economic development and social changes. Therefore, Indonesia may be at the start of the dietary transition, Korea at the middle of the transition, and the US has somewhat stabilized after the transition. Epidemiological transition also showed different pattern by development stage. Indonesia showed the general pattern of epidemiological transition, that is, increasing patterns of chronic diseases and decreasing pattern of infectious disease (TB). However, the general pattern was not observed in Korea and the US. High blood pressure prevalence decreased in both Korea and the US. The US also showed decreasing prevalence of meal total cholesterol, in addition to that of high blood pressure.

Contrary to dietary transition, nutrition transition found only one significant trend: increasing consumption of fat in Korea. No other significant trends were found. While dietary transition was based on food availability data (FAO Food Balance Sheet), nutrition transition was based on food consumption data. Therefore, one could suspect that food availability has been significantly changing, but food consumption may be lagged behind. Another possibility could be that changing trends may have been lost through dietary assessment methods and conversion of food information to nutrient information. Similar finding was also reported (1).

Body weight transition was occurring into one direction in all three nations: increasing of overweight and obesity. The size of increase differed by development stage. The most developed country, the US, reported the highest level of overweight and obesity in both men and women. Patterns in prevalence of overweight and obesity were somewhat mixed in Indonesia and Korea. Korean women showed lower prevalence of overweight since 2010 and obesity since 2000 than Indonesia women, which was the opposite of what was expected. No such results were found in men. Desire to be thin has been very strong in Korean women (28). This social pressure could be a factor for the unexpected findings. Cross-national significant testing was not possible because the data sources did not provide standard deviations, therefore, the difference between Korea and Indonesia may not be significantly. Nonetheless, this phenomena deserves further attention to explore whether the social pressure could result in only positive health outcomes without negative ones such as eating disorders (29-30).

The previous study on transitions in Korea (1) reported that body weight transition was significantly associated with physical activity and nutrition transition, and that physical activity transition appeared to have higher impact on body weight transition than nutrition transition. This study also found that body weight transition was significantly related to physical activity transition and dietary transition. The higher impact of physical activity on body weight transition was found only in women. This difference may have come from the fact that the model of system of transition in this study could not include nutrition transition.

The model of system of transition in the three nations, structured by path analysis, had similarities and differences. The most notable similarity is that transitions were generally significantly associated with each other with only two exceptions. That is, physical activity transition and dietary transition was significantly associated with socio-economic transitions, and body weight transition was significantly affected by physical activity and dietary transition. Epidemiological transition was highly related to body weight transition. The notable difference was relative size of effects from physical activity and dietary transition on body weight transition. It seems that physical activity transition more strongly affect body weight transition than dietary transition at the stage of developing, but dietary transition had more effects on body weight transition than physical activity transition at the stage of most developed. This study used proportion of population employed in agriculture sector as a proxy for physical activity transition. The US and Korea at certain degree had completed industrialization before the beginning of the study period (1980s), therefore, the proportion of population employed in agriculture sector did not change much in the US and Korea. Further studies would be needed to determine whether this relative size of impact were really existing or originated from an assessment method.

Our findings regarding changes in transition indicators in Indonesia appear to comply with "nutrition-related noncommunicable disease" pattern proposed by Popkin (14), supported by both increasing consumption of vegetable oil, milk, and meat and increasing prevalence of overweight and obesity, and chronic diseases. The significantly decreasing prevalence of high blood pressure and mean total cholesterol could put the US into "behavioral change" pattern, but findings in dietary, nutrition, and physical activity transition along with continued increase of overweight and obesity have difficulty with supporting the pattern. Therefore, it would be safe to state that Korea and the US seem to be at between "nutrition-related noncommunicable diseases" and "behavioral change" pattern.

Several limitations of the present study warrant consideration. This study used aggregated data on the national level, therefore, limitations of using aggregated data can be applied to this study. For instance, the high correlations found in this study could come from the use of aggregated data. Limitations of data collection can also be applied to this study. Physical activity transition was represented by indirect indicators of proportion of population employed in different economic sectors rather than direct indicators such as daily energy expenditure. Such data were simply not available. In addition, recreational physical activity was not considered in this study. Socioeconomic transition may be associated with decreasing occupational physical activity and increasing recreational physical activity (9), therefore, incorporation of recreational physical activity may have an impact on findings of this study. This study examined approximately 35 years from 1980 to 2015. Extending the study period further back was not possible because data were not available. Perhaps the most important limitation of this study was use of time-series of cross-sectional data. Since they were not prospective longitudinal data, causal relational establishment is difficult.

Despite its limitations, the present study is the first to examine the socio-economic, dietary, nutrition, physical activity, body weight, and epidemiological transitions in multiple nations at varying stage of development. This study advanced the knowledge (1,14) by replicating the previous study (1) with more recent data, comparing three nations at different development stage, and including epidemiological transition in addition to the other transition. Two types of datasets were suggested as ideal to examine the system of transition (1): longitudinal data on individuals in a country that underwent rapid development and longitudinal aggregated data from multiple nations at different stages of development. This study attempted the latter in a small scale.

This study found that the transitions were at different level by stage of development and the transitions were associated each other as shown in the system of transition. These findings remind us to view current nutrition and health problems more systematic ways rather than just on the individual levels (31,32). What should be noted from this study is that while the US, the most developed, and Korea, developed, showed some reverse, such as decrease of high blood pressure prevalence, in epidemiological transition, no meaningful reverse changes in behaviors (dietary, nutrition, and physical activity transitions) were observed. Given the amount of efforts that took place to change behaviors (33-36), no meaningful changes in behaviors to healthier ways was a little disappointing. Future studies are needed to understand how such reverse in epidemiological transition could have been achieved without meaningful changes in behaviors and how much more reverse in epidemiological transition could be achieved or sustained without changes in dietary, nutrition, and physical activity transitions. More importantly, efforts to move dietary, nutrition, and physical activity transitions to healthier ways should be continued.

Acknowledgement

This manuscript is a revision of the first author's Master degree thesis at Inha University. There are no conflicts of interest. This study was supported by Inha University Research Grant.

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