

# Socio-economic, dietary, activity, nutrition and body weight transitions in South Korea

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## Abstract

*Objective:* Socio-economic development influences many factors that affect health, especially diet and nutrition. This investigation proposes that a system of transitions occur as societies develop, with socio-economic, physical activity, dietary, nutrition and body weight transitions operating in relationship with each other. This model of transitions was examined empirically using South Korea as an example of a nation that has undergone considerable changes.

*Design:* Data were drawn from published government reports: the Korean National Nutrition Survey and annual reports at the national level for the years between 1969 and 1993. The socio-economic transition was assessed by gross national product. The physical activity transition was assessed using annual proportions of the population involved in primary, secondary and tertiary industries, as well as the number of cars and driver's licences. The dietary transition was measured by plant and animal food consumption. The nutrition transition was assessed by percentages of energy from carbohydrate, protein and fat. The body weight transition was measured by body mass index calculated from the average height and weight of adolescents.

*Results:* Results revealed that the transitions were highly correlated as expected, with the socio-economic transition exhibiting major changes. South Koreans tended to decrease their physical activity and plant food consumption, and to increase animal food consumption, percentage of energy from dietary fat and body weight, in relationship to the socio-economic transition.

*Conclusion:* Examining a system of transitions on a national level in one country that has undergone rapid economic development may provide a strategy for examining how such transitions operate in other nations.

**Keywords**  
Socio-economic  
Dietary  
Activity  
Nutrition  
Weight  
Transitions  
South Korea

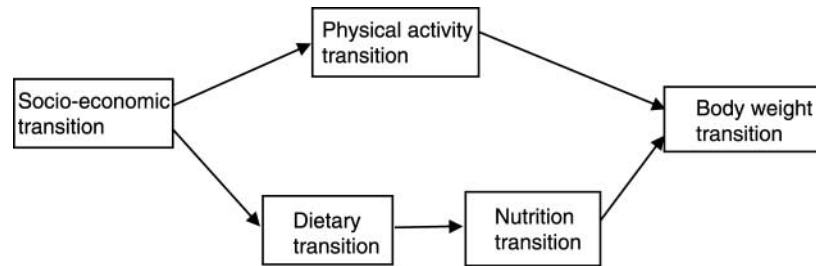
Public health is influenced by interrelationships among many factors in society. Economic development is an important influence on factors that affect health, especially diet and nutrition. This investigation proposes that a system of transitions occur as societies develop, with socio-economic, physical activity, dietary, nutrition and body weight transitions operating in relationship with each other. The proposed system of relationships between these transitions is shown in Fig. 1, where socio-economic transitions influence activity and dietary transitions, which in turn lead to transitions in body weight. Other transitions also occur as part of the system of transitions associated with development, including demographic transitions<sup>1</sup>, mobility transitions<sup>2</sup>, epidemiological transitions<sup>3–5</sup> and others that will not be considered here in an attempt to focus on public health nutrition issues.

Socio-economic transitions occur as societies undergo social changes during modernisation and economic

development<sup>6,7</sup>. As societies industrialise, the relative economic size of agriculture sectors declines, the manufacturing sector increases and the service sector increases<sup>8</sup>. Sectoral changes are reflected in societal shifts in overall economic productivity, individual household incomes and human capital development of the population<sup>8</sup>. The geographic distribution of the population is also affected. The majority of people tend to live in rural areas before economic development; however, more and more congregate in urban areas as economic development proceeds<sup>9,10</sup>.

Physical activity transitions are influenced by socio-economic transitions. The level of physical activity decreases with the declining proportion of the population involved in agricultural work and the increasing proportion of the population involved in service work<sup>11</sup>. Physical activity transitions lead to less physical energy expenditure on the job<sup>12,13</sup>. The mode

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**Fig. 1** A system of relationships between transitions

of movement also changes, from walking to mass transportation to driving a car, which decreases total expenditure from physical activity<sup>14,15</sup>.

Dietary transitions involve shifts in the foods consumed in a society<sup>7,16</sup>. Dietary behaviours are an important part of social structure and social processes, and as societies change diets also change. Dietary transitions are closely correlated with income level<sup>17–19</sup>. The major aspect of the dietary transition occurs as diets are delocalised<sup>20</sup>, and fewer locally produced plant foods and more imported and processed animal foods are consumed. Another aspect of the dietary transition is uncoupling of food preparation from food consumption<sup>21</sup>. Traditionally, foods were consumed by whom and where they were prepared. However, as women who are the traditional food handlers increasingly enter the paid labour force, food consumption outside the home such as take-out foods, eating out and fast foods increases<sup>14,21,22</sup>. Dietary transitions have also been propelled by technological advances in food processing and packaging<sup>7</sup>.

Nutrition transitions occur as economic changes transform the food system of a society to provide a different mix of nutrients<sup>11,23–29</sup>. As societies change from traditional to industrialised, the proportions of macronutrients consumed change to include more protein, more fat and less carbohydrates<sup>30</sup>. Micronutrient consumption is also affected; while nutrient deficiency tends to disappear with economic development, fibre consumption tends to decline. These nutritional changes reflect dietary transitions. Higher consumption of processed foods may result in lower micronutrient consumption, but it may also increase micronutrient consumption if the processed foods are fortified. Increased consumption of animal foods may lead to higher protein and fat consumption.

Body weight transitions involve shifts in the overall level of body fat of people in a society<sup>13</sup>. In traditional societies, individuals are often undernourished and rarely obese, while in industrialised societies people are often obese and less often thin<sup>13</sup>. Body weight transitions occur as a part of societal changes that influence diet and physical activity. As societies pass through the socio-economic, physical activity, dietary and nutrition transitions, social conditions facilitate weight gain<sup>14</sup> and the desire for a thin body<sup>13</sup>.

South Korea is a nation that has undergone considerable social change during the last few decades, and the patterns of South Korean social, nutritional and health changes have been especially striking. The proposed model of development as a system of transitions is examined empirically in the present paper using South Korea as an example. Examining how this system of transitions occurs on a national level in one country that has recently undergone rapid economic development may provide an example of how such transitions may operate in other nations.

## Methods

### Sample

The sample for this analysis is national data available for the years between 1969 and 1993 in South Korea. The initial year of 1969 was chosen because the Korean National Nutrition Survey started that year, and several variables in this study were extracted from that survey. The ending year of 1993 was selected because classification of occupation was changed as of 1994, making comparison with subsequent years impossible. These 24 years are a time when considerable social changes occurred in South Korean society.

### Measures

National population-level data are available as a series of indicators of socio-economic, physical activity, dietary, nutrition and body weight transitions. All of the data came from published South Korean government reports. Most of the data used in this study are also available at South Korean government websites ([www.korea.net](http://www.korea.net) and [www.nso.go.kr](http://www.nso.go.kr)).

Three indicators of socio-economic transitions included gross national product (GNP), percentage of the population that is urban and percentage of high school graduates. The GNP indicates the goods and services produced by a country as a whole, and has been used as an indicator of development of a national economy<sup>8</sup>. The percentage of urban population shows how much urbanisation has occurred. The percentage of high school graduates reflects the development of human capital through education. GNP and percentage of urban population were obtained from the *Korean Statistical*

*Yearbook*<sup>31</sup> and the percentage of high school graduates was taken from *Social Indicators in Korea*<sup>32</sup>. Data on percentage of urban population were available every five years until 1988 and yearly after that, and the percentage of high school graduates was available every five years.

Physical activity transitions for the nation as a whole were assessed using three related indicators. The annual proportion of the population involved in primary (agricultural), secondary (manufacturing) and tertiary (service) industries was calculated. Industrial activity reflects the amount of energy expenditure at work, ranging from the heavy physical work involved in farm production to the sedentary activity of office work<sup>7,11</sup>. The South Korean government used six employment categories: (1) professional, technical, administrative and managerial workers; (2) clerical and related workers; (3) sales workers; (4) service workers; (5) agriculture-, forestry- and fishery-related workers; and (6) production, transportation, equipment operation and labours. The first four categories were collapsed to represent tertiary industries. Although they are different types of industry, the amount of physical activity involved in these industries is similar, compared with the other industries. The proportion of the population involved in agriculture-, forestry- and fishery-related work was used to represent primary industry. The proportion of the population involved in production, transportation, equipment operation and labour was used to represent secondary industry. This information was obtained from the *Korean Statistical Yearbook*<sup>31</sup>.

The number of cars and the number of driver's licences were also used to reflect modes of people's daily movement, with driving indicating less physical activity than walking, bicycling or using mass transportation. This information was taken from the *Statistical Yearbook of Transportation*<sup>33</sup>.

Dietary transitions were measured using two groups of indicators. The first group included the Engel Index and eating-out expenditure. The Engel Index is the percentage of income spent on food that is purchased from sources outside the home such as markets and restaurants, and has an inverse relationship with economic development<sup>34</sup>. Eating-out expenditure indicates the proportion of income used to consume food outside the household. South Korea national averages for the Engel Index and eating-out expenditure were not available; however, separate averages for urban and rural areas were available. Engel Index and eating-out expenditure for rural areas are available from 1976 onwards, while those for urban areas from 1969 onwards were found in *Social Indicators in Korea*<sup>32</sup>.

The second group of dietary transition indicators consisted of proportions of energy, protein and fat supplied from animal and plant foods, and energy consumption from cereals. Energy from cereal grains is important because rice is a staple in the South Korean

diet<sup>35</sup>. Energy, protein and fat consumptions from animal and plant foods were taken from the Food Balance Sheets<sup>36</sup>. Data on fat consumption from 1969 to 1974 are not available. Energy consumption from cereal grains was taken from the Korean National Nutrition Survey Reports<sup>37,38</sup>. The Korean National Nutrition Survey Report is an annual survey of households that assesses a variety of nutritional parameters of household members and reports annual aggregate data for the nation as a whole.

Nutrition transitions were measured by aggregated data on how much energy was contributed to people's intake from carbohydrates, protein and fat. These data were obtained from the Korean National Nutrition Survey Reports<sup>37</sup>.

Body weight transitions were assessed using average body mass index (BMI) of adolescents at the age of 17 years. Height and weight of adolescents in high schools are measured annually and aggregated height and weight for each age are reported in the *Statistical Yearbook of Education*<sup>39</sup>. From those heights and weights, BMI was calculated using the relationship: weight (in kg) divided by the square of height (in m). BMI is used widely in nutritional epidemiology as a population-based measure of the amount of body fat and level of obesity<sup>40</sup>, including studies on adolescents<sup>41</sup>.

### Analysis

The time series data from each of the indicators were first examined by year for each of the transitions to describe patterns in the data over time. The theoretical model presented in Fig. 1 was examined with path analysis using the CALIS procedure in SAS software<sup>42</sup>. One indicator from each transition was selected by examining correlations among the multiple indicators within each type of transition. For the socio-economic transition, GNP was the only variable for which values were available for all years. The proportion of tertiary industry was chosen for the physical activity transition because it was highly correlated ( $r = 0.82$  to  $0.98$ ) with other indicators and carries theoretical significance of work-related physical activity. Percentage energy from cereal grains was used to represent the dietary transition because of its high correlation ( $r = 0.87$  to  $0.92$ ) with other indicators and its substantive importance as a representation of starchy staples intake<sup>18,30</sup>. Percentage energy from fat represented the nutrition transition for the same reasons. The body weight transition was represented by the average BMI of 17-year-old males and females. Log transformation was performed on GNP to normalise the distribution to produce better path models<sup>43</sup>.

## Results

### Socio-economic transition

South Korea proceeded rapidly through a socio-economic transition during the years examined here. The GNP of

South Korea increased more than 50-fold over the 24 years, from \$66 billion to \$3308 billion (Table 1). The proportion of the population living in urban areas also grew from 41.1% in 1970 to 76.3% in 1993, while the percentage of the population with a high school diploma increased from 10% in 1970 to 33.5% in 1990. GNP was very strongly related to urban population ( $r = 0.89$ ,  $P < 0.0001$ ) and population with a high school diploma ( $r = 0.94$ ,  $P < 0.05$ ).

### **Physical activity transition**

In South Korea, physical activity decreased in job-related and transportation areas. The physical activity transition was assessed using two types of proxy variable. Proportions of the working population in industry sectors indicated physical activity at work. Over the years examined here, the number of people in the primary industry sector (agriculture, fishing and forestry) decreased significantly, while the number of people in the tertiary industry sector (service industries) reached more than half the working population in South Korea (Table 1). Therefore, physical activity from work appears to have decreased substantially at the national level. The proportion of the population in the primary industry sector was negatively associated with the proportions of the population in the secondary sector ( $r = -0.95$ ,  $P < 0.001$ ) and the tertiary sector ( $r = -0.98$ ,  $P < 0.0001$ ), while the secondary sector and the tertiary sector were positively associated ( $r = 0.86$ ,  $P < 0.0001$ ).

The second type of proxy variable (number of passenger cars and number of driver's licences) for a physical activity transition examined the mode of people's transportation. The number of driver's licences started to go up from 1978 and increased steadily from then on, although the number of passenger cars did not increase substantially until the late 1980s (Table 1). During the 1980s, many South Koreans began to obtain a driver's licence even if they did not own a car at that time. It is assumed that public transportation was the major mode of movement for South Korean people until 1990, when more individuals began to own cars. The number of passenger cars and the number of driver's licences were highly correlated ( $r = 0.97$ ,  $P < 0.0001$ ). The proportion of the population in the primary industry sector showed a consistent and significant negative relationship with the number of passenger cars ( $r = -0.77$ ,  $P < 0.0001$ ) and the number of driver's licences ( $r = -0.89$ ,  $P < 0.0001$ ), while the proportions of the population in the secondary and tertiary industry sectors showed a significant positive relationship ( $r = 0.86$ ,  $P < 0.001$ ).

### **Dietary transition**

South Koreans' diets changed substantially over this period. The Engel Index fell significantly from the late 1970s for both urban and rural areas, from 46.9% to 29.6% and from 45.7% to 21.9%, respectively (Table 1).

The income urban and rural households spent on foods consumed outside the home grew from less than 1% to approximately 8% for urban residents and 4% for rural residents. This away-from-home spending increase for food started in the late 1980s. The Engel Index in urban areas was positively related to the Engel Index in rural areas ( $r = 0.98$ ,  $P < 0.0001$ ), while the Engel Index in both urban and rural areas was negatively related to the percentage of income urban and rural households spent on foods away from home ( $r = -0.95$ ,  $P < 0.001$  and  $r = -0.93$ ,  $P < 0.001$ , respectively).

The supply of animal foods increased, while the supply of plant foods decreased (Table 1). The energy supplied from animal foods was about 5% in 1970 and increased threefold over the 24 years. The energy supplied from plant foods decreased from 95% to 86%. Energy consumed from cereal grains decreased more substantially, from 86% to 64%. Therefore, over the period studied, South Koreans consumed more animal foods and less plant foods, while the dependency on cereals as a staple source of energy decreased drastically. The percentage of energy supplied from plant foods was negatively associated with the percentage of energy supplied from animal foods ( $r = -1.00$ ,  $P < 0.0001$ ) and positively associated with the percentage of energy supplied from cereal grains ( $r = 0.91$ ,  $P < 0.0001$ ).

More protein and fat were consumed from both animal and plant foods. Total protein consumption per capita per day increased steadily over the years, and the increase was primarily from animal protein. Total protein consumption was positively related to the percentage of protein supplied from plant foods ( $r = 0.72$ ,  $P < 0.001$ ) and the percentage of protein supplied from animal foods ( $r = 0.99$ ,  $P < 0.001$ ). By contrast, the rising consumption of fat from plant oils appears to have contributed substantially to the increasing total fat consumption. While plant fat consumption increased almost fourfold, animal fat consumption increased about only twofold. Total fat consumption was associated with the percentage of fat supplied from plant foods ( $r = 1.00$ ,  $P < 0.0001$ ) and the percentage of fat supplied from animal foods ( $r = 0.95$ ,  $P < 0.0001$ ).

All of these measures of dietary transitions were significantly related to each other (all  $P < 0.05$ ), with the Engel Index and the percentage of income spent on away-from-home foods showing the opposite direction of correlation to the other measures. Lower Engel Indexes were positively associated with higher energy consumption from animal foods and higher protein and fat consumption from both plant and animal foods.

### **Nutrition transition**

The dietary transition led to the nutrition transition, represented by increased energy from protein and fat and decreased energy from carbohydrates (Table 1). In 1969, Koreans acquired 80% of their energy consumption from

**Table 1** Values for socio-economic, physical activity, dietary and nutrition transition indicators in South Korea, 1969–1993

Transition	Year																																	
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993									
<i>Socio-economic transition</i>																																		
Gross national product (\$billion)	66	81	95	107	135	188	209	287	368	516	616	606	671	717	800	881	911	1054	1334	1798	2204	2518	2920	3057	3308									
Urban population (%)	41.1						48.4					57.3					69.3			72.2	73.1	74	74.8	75.6	76.3									
High school graduate (%)	10.2						13.9					18.9					25.9																	
<i>Physical activity transition</i>																																		
Primary industry (%)	50.7	50.2	48.4	50.7	49.9	48.1	45.8	44.6	41.6	38.4	35.7	34	34	31.8	29.5	26.8	24.6	23.4	21.7	20.5	19.4	17.8	17.8	15.6	14.6									
Secondary industry (%)	20.8	20.2	19.6	20.7	21.9	22.6	24.1	26.1	27.5	29.2	30	29	28.2	27.7	28.4	30	30.3	31.6	33.4	34.2	34.6	34.8	34.8	33.6	31.9									
Tertiary industry (%)	28.5	29.6	32.5	28.7	28.2	29.1	30.1	29.3	30.9	32.5	34.4	35.7	37.6	40.9	42	43	45.1	45.2	44.9	45.3	45.9	47.4	47.9	50.8	53.4									
Number of cars (1000 s)	50	61	68	70	78	76	84	96	126	185	241	249	268	306	381	465	557	664	844	1118	1559	2075	2728	3461	4271									
Number of driver's licences (100 000 s)	3	4	5	6	7	7	7	8	9	11	15	19	22	26	30	35	41	47	53	62	72	85	98	116	133									
<i>Dietary transition</i>																																		
Engel Index in urban areas (%)	46.9	46.9	47.6	47.8	48.1	49.8	48.8	47.6	47.4	45.5	42.6	43	42.6	41.3	39.5	38.5	37.7	36.4	35.5	34.9	32.4	32.7	32.7	30.6	29.6									
Engel Index in rural areas (%)							45.7	42.8	38.8	37.8	36.8	37.7	37.7	33.3	30.4	29.4	28.4	27.4	26.9	26.2	23.9	23.5	22.8	23.3	21.9									
Income spent on eating out in urban areas (%)	0.9	0.9	0.9	0.9	1	1.4	1	1	1.5	1.6	1.7	1.8	2	2.8	2.9	3	3.1	3.5	4.6	5.1	6.5	7	7.3	7.6	8.2									
Income spent on eating out in rural areas (%)							1.4	1.6	1.4	1.4	1.4	1.5	1.8	2.1	2.9	3	3	3	2.9	3	3.2	3.6	4	4.1										
Total energy supply (kcal day <sup>-1</sup> )	2309	2370	2469	2415	2416	2371	2390	2414	2427	2533	2599	2485	2531	2588	2622	2636	2687	2746	2810	2814	2825	2853	2876	2912	2872									
Total energy consumption (kcal day <sup>-1</sup> )	2105	2150	2072	1904	2059	2054	1992	1926	2134	1833	2098	2052	2052	1991	2101	1901	1936	1930	1819	1935	1871	1868	1930	1875	1848									
Energy from plant foods (%)	94.9	95.1	94.3	93.8	93.5	92.6	92.6	92.0	90.4	90.9	90.4	90.8	90.2	89.9	89.3	88.2	88.7	88.7	88.2	88.0	87.5	86.1	87.1	86.3	85.8									
Energy from animal foods (%)	5.1	4.9	5.7	6.2	6.5	7.4	7.4	8.0	9.6	9.1	9.6	9.1	9.8	10.1	10.7	11.8	11.3	11.4	11.8	12.0	12.5	13.8	12.9	13.7	14.2									
Energy from cereal grains (%)	85.9	81.2	84	83.6	82.4	82.1	82.5	82.3	77.7	78	77.4	77.7	75.5	77.9	75	72.9	61.9	69.5	67.3	67.1	66.5	65.8	65.8	66.5	63.8									
Total protein consumption (g day <sup>-1</sup> )	63.5	65.1	67.1	67.1	70	69.4	71.1	73.5	73.9	73.8	76.2	73.6	76.9	78.3	86.6	85.6	86.6	89.4	88.4	87.5	88.9	89.3	88.6	90.1	91.7									
Total plant protein consumption (g day <sup>-1</sup> )	53.1	54.5	56.7	54.6	55.5	55.3	55.9	56.4	53.7	55.2	56	53.5	55.2	55.6	57.6	56.5	58.1	58.6	57.7	58.3	58.3	56.1	56.2	56.5	56.2									
Total animal protein consumption (g day <sup>-1</sup> )	10.4	10.6	10.4	12.8	14.5	14.1	15.2	17.1	20.2	18.6	20.2	20.1	21.7	22.7	29.1	29.1	28.5	30.9	30.7	29.2	30.7	33.2	32.4	33.6	35.5									
Total fat consumption (g day <sup>-1</sup> )	19.7						27.4	27.9	29.2	33.1	37.5	36.6	39.2	44	47.1	49.2	51.8	53.6	58.2	60.4	61.6	72.2	71.7	73.6	74.1									
Total plant fat consumption (g day <sup>-1</sup> )							14.1	15.2	13.5	16.4	19.8	21.4	22.8	26.5	31.2	30.1	33.5	35.8	38.2	39.4	39.6	46.7	48.6	48.2	48.6									
Total animal fat consumption (g day <sup>-1</sup> )							13.3	12.7	15.7	16.7	17.7	15.2	16.4	17.5	15.9	19.1	18.3	17.8	20	21	22.1	25.5	23	25.4	25.5									
<i>Nutrition transition</i>																																		
Energy from carbohydrates (%)	80.3	78.5	80.7	77.6	79.1	80	80	77.3	74.9	75.9	75.5	77.3	77.3	77	73.7	74	70.9	71.5	69.7	70.6	70	66.5	68.3	67.6	65.9									
Energy from protein (%)	12.5	12.6	13	13.6	12.5	13.2	12.8	12.5	13.3	13	13.3	13.1	13.7	13.5	13.8	14.6	15.4	15.4	15.6	16.4	16.1	16.9	15.1	15.8	15.9									
Energy from fat (%)	7.2	8.9	6.3	9.1	8.4	6.8	8.6	9.6	11.8	11.1	11.2	9.9	9	9.5	12.5	11.4	13.7	13.1	14.7	13	13.9	16.6	16.6	18.2										

carbohydrates, while approximately 66% of energy came from carbohydrates in 1993. Percentage energy from fat showed the opposite pattern. Fat provided more than twice as much energy to South Koreans in 1993 (18.2%) than in 1969 (7.2%). Interestingly, percentage energy from protein did not change as much as percentage energy from fat. Protein provided 13% of daily energy in 1969 and 16% in 1993. Most changes in the nutrition transition occurred in carbohydrate and fat intakes. While percentage energy from carbohydrate was negatively related to percentage energy from both protein ( $r = -0.92, P < 0.0001$ ) and fat ( $r = -0.98, P < 0.0001$ ), the percentage energy from protein and fat were positively related to each other ( $r = 0.85, P < 0.0001$ ).

### Body weight transition

The average BMI of 17-year-old adolescents increased steadily over this time period (Fig. 2). Girls showed less of an increase in average BMI than boys. Changes in the average BMIs of girls and boys were significantly correlated ( $r = 0.86, P < 0.0001$ ).

### Relationships among transitions

Results of the path analysis are presented for each gender in Figs 3 and 4. Path analysis showed a relatively good fit of the model to the data. The model with 17-year-old boys (Fig. 3) revealed standardised residuals less than 0.05, a normed fit index (NFI) of 0.92, a comparative fit index (CFI) of 0.94 and a significant chi-square test ( $\chi^2 = 17.22, P = 0.004$ ). These indicators of standardised residuals, NFI, CFI and chi-square are used to assess the goodness-of-fit of the tested models. Since models are not considered a good fit if standardised residuals are greater than 1, NFI and CFI are less than 0.9, and there is a non-significant chi-square test<sup>42</sup>, the model with 17-year-old boys appeared to be a good fit by meeting three out of four criteria. All path coefficients in the model with 17-year-old

boys were significant at  $P = 0.001$ . The model with 17-year-old girls (Fig. 4) also showed a relatively good fit, with standardised residuals less than 0.5, NFI = 0.89, CFI = 0.92 and a significant chi-square test ( $\chi^2 = 17.95, P = 0.003$ ). In the model with 17-year-old girls, the path coefficient (0.08) leading from the nutrition transition to the weight transition was not significant at  $P = 0.05$  ( $t = 0.3843$ ).

Standardised path coefficients showed that GNP had a strong influence on the proportion of tertiary industry and the percentage energy from cereals. Percentage energy from cereals was inversely related with percentage energy from fat. Average BMI of 17-year-old boys had path coefficients of 0.54 with proportion of tertiary industry and 0.46 with percentage energy from fat. Average BMI of 17-year-old girls had a higher path coefficient (0.68) with proportion of tertiary industry and a lower path coefficient (0.08) with percentage energy from fat. It should be noted that the weight transition in 17-year-old girls had the highest residual of 0.67 compared with other transitions.

### Discussion

As South Korea went through rapid economic development, there were significant changes in the physical activity, diet, nutrition and body weight of the population. South Koreans have used less energy in job-related activity and transportation over time. Simultaneously, their diet has incorporated more animal foods and plant oils. Increased consumption of plant oils was largely responsible for a higher proportion of energy coming from fat. The relative body weights of adolescents showed a steady increase.

Separation of food consumption from food preparation occurred in South Korea, as shown by increasing expenditures on eating out. This trend was displayed more dramatically in the growth of the South Korean fast food and convenience food industries<sup>44</sup>. Until the late

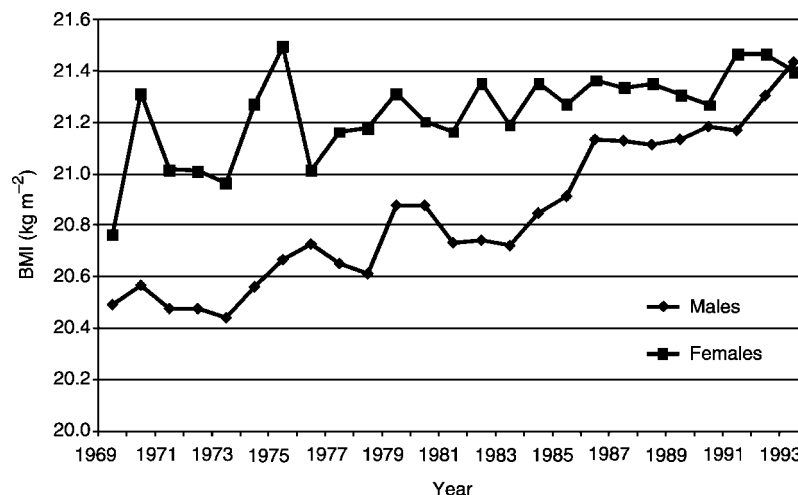
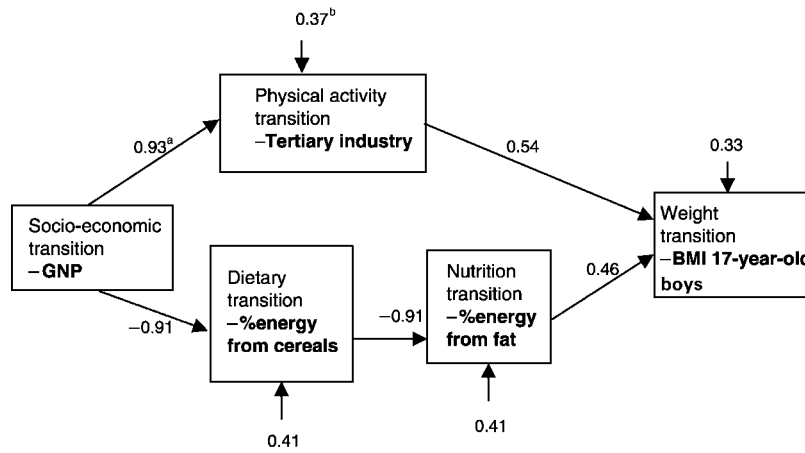


Fig. 2 Weight transition: changes in body mass index (BMI) of 17-year-old adolescents



a. Numbers on the arrows between transition boxes are path coefficients  
 b. Numbers on the outside arrows pointing into transition boxes are residuals

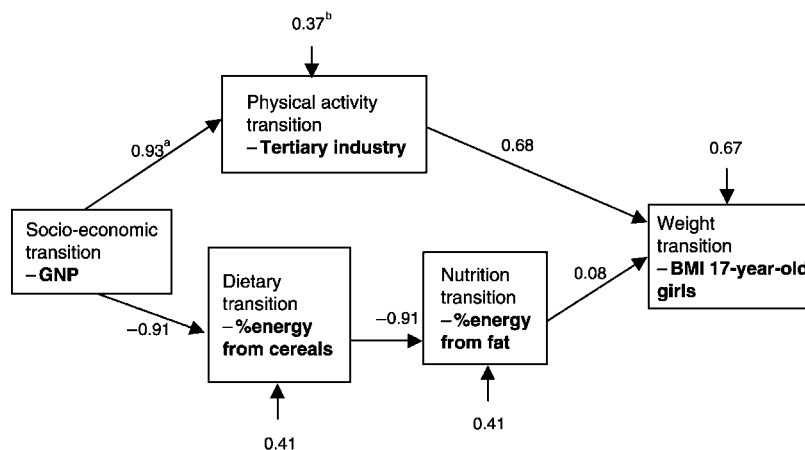
**Fig. 3** A model of a system of transitions in the average body mass index (BMI) of 17-year-old boys (GNP – gross national product)

1970s, many households made their own Korean soybean paste that is essential in Korean cuisine, but now nearly every household purchases Korean soybean paste from markets. This trend also occurred in other essential ingredients of Korean cuisine, including the staple vegetable dish *kimchi*. Increasing food imports have created anxiety in South Korea, such as the crisis over possible foot-and-mouth disease from imported beef and the high lead content of seafood imported from China<sup>45</sup>.

Changes in food items consumed in South Korea were substantial. Rice has been a vital staple for Koreans throughout history. The decline in percentage energy from cereal grains, from 86% in 1969 to 64% in 1993, showed that South Koreans have begun to consume more of other food items. While plant foods still provided more than 80% of food energy in 1993, the percentage energy from animal foods almost tripled during the years examined here (5% to 14%). This increase in animal food

consumption contributed significantly to both protein and fat intakes. Since consumption of total plant protein virtually did not change over the time period, the increase of total protein consumption resulted from animal food consumption. However, the dramatic increase in fat intake, while relatively low compared with other countries, was clearly propelled by plant fat consumption. The increase in plant fat consumption was almost twice that of animal fat consumption. Contribution of plant-based foods to fat intake was reported in a study that used a total food duplicate method<sup>46</sup>. The importance of fat from plant sources has also been demonstrated in other countries<sup>30</sup>.

What is not clear is whether and how dietary transitions were associated with total energy consumption. Korea Food Balance Sheets reported that total energy supply per capita increased from 2309 kcal in 1969 to 2872 kcal in 1993; however, the Korean National Nutrition Survey



a. Numbers on the arrows between transition boxes are path coefficients  
 b. Numbers on the outside arrows pointing into transition boxes are residuals

**Fig. 4** A model of a system of transitions in the average body mass index (BMI) of 17-year-old girls (GNP – gross national product)

Reports showed that actual energy consumption by individuals declined from 2105 kcal in 1969 to 1848 kcal in 1993. The Korean population has matured<sup>47</sup>, with an increasing median age of the population (18.5 years in 1970 to 27 years in 1990) and a decreasing proportion of individuals younger than 14 years (41% in 1969 to 24% in 1993). Individuals over 65 years old accounted for only 3% (1969) to 5% (1993) of the total population. Therefore, this discrepancy seems to show that South Koreans consumed less energy with different macronutrient profiles over the years in an increasingly food-abundant environment. Since the Korean National Nutrition Surveys used a direct weighing measuring method for assessing household food consumption, underreporting of dietary intake affected by changing social norms emphasising low body weight is not a valid explanation for these dietary changes. This pattern needs to be explored further in relation to body weight transitions on both the individual and the national level.

A body weight transition occurred in South Korea and was predicted by other transitions. The path models showed that the coefficients of the path from the activity transition to the body weight transition were somewhat higher than the coefficients of the path from the nutrition transition to the body weight transition in both adolescent boys and adolescent girls. This finding should be evaluated in the light of other considerations. For example, total caloric consumption, and not only dietary fat, is important in relation to body weight<sup>48</sup>, and caloric intake was not controlled for this analysis. This analysis also did not address the social pressure for girls to be thin, which leads girls to participate in purposeful weight control and diets<sup>49</sup>. This social pressure is significantly associated with economic development, and may be mediating the relationship between the nutrition transition and the body weight transition. This is supported by the finding that girls had a higher residual (0.67) than did boys (0.33) in the path model, meaning the proposed model explained the body weight transition of boys better than girls. Inappropriate weight control or dieting is an area that needs much attention from public health nutritionists in relation to obesity.

Changes in each transition described here have been reported in other Asian countries<sup>50–53</sup>. As countries achieve economic development, people seem to consume more animal food-based and high-fat diets and to engage in less physical labour. Lee *et al.*<sup>54</sup> reported that South Korea uniquely has a relatively low prevalence of obesity and a lower level of total dietary fat compared with other Asian countries. Recently, South Korea has witnessed much interest in body weight management across all ages and genders, as well as dramatic growth in the weight loss industry especially targeting women. Combined with a finding of this study that the average BMI changed more among boys than girls, this suggests that it may be possible that South Korea will reverse its course in body weight

transition, at least among women, as Japan has<sup>55</sup>. Analysis of a body weight transition over 20 years (1976–1995) in Japan showed that while the average BMI increased by half a unit each year among men, the average BMI actually decreased – albeit slightly – each year among women<sup>55</sup>.

This study was limited by using aggregated data on the national level, although it used time series data. Use of correlations and path analysis for time series data has several limitations. Some of the high correlations may be due to use of aggregated data<sup>56</sup>. This study inherited the shortcomings of the methods used in data collection. Food balance sheets can only provide food supply data, not actual food consumption of individuals. The Korean National Nutrition Survey provided information about food consumption; however, it has its own limitations including the use of household-based food assessment methods<sup>57</sup>. The survey utilised the direct food weighing method on the household level because South Koreans share all foods at the same table. The nutrient information calculated from the weighted food information was then divided into each individual's share in the household, using specific conversion factors based on age and sex. While this method may not provide accurate food consumption data on the individual level, it may provide more meaningful food consumption data on the population level. This study was also limited by indirect indicators for transitions, such as use of employment structure and the number of cars for representing the physical activity transition. These indirect indicators may not provide information about the actual amount of physical activity, however they can provide valuable social indicators of activity on the population level. This study was not able to include recreational physical activity because there were no national data available. However, since recreational physical activity tends to become significant with greater economic development, it would be important to examine this transition in future analysis. Perhaps the most important data that were not available are the proportions of individuals who were overweight and obese. This information would have been able to more completely represent the extent of the body weight transition.

In future research, two types of datasets would be ideal for studying how transitions are interrelated each other: longitudinal data on individuals in a country that experienced rapid socio-economic development and longitudinal aggregated data from many countries in different stages of socio-economic development. However, most developing countries did not begin their health and nutrition surveillance early enough to permit adequate historical comparisons. In turn, valid and comparable longitudinal aggregated data from many countries in different stages of socio-economic development are also not available for extensive multinational comparisons.

The finding that a body weight transition was associated with both physical activity and nutrition transitions



indicated that it is important to think about the issue of the trend of increasing obesity using wider and more systematic approaches. The trend of increasing obesity cannot be changed only by educating individuals about eating and exercise; what is also required is to deal with the way societies facilitate healthy food consumption and physical activity<sup>14,58</sup>.

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