Comparison of Clusters by Eating Habits between Five and Six Years Old: A Panel Survey Analysis on Korean Children

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Submitted to: JMIR Public Health and Surveillance
on: August 04, 2023

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Abstract

Background: Early childhood obesity is becoming a public health concern due to its increasing prevalence all over the world. Establishing healthy eating habits and lifestyles in early childhood may help children to gain appropriate weight and further improve their health outcomes later in life.

Objective: This study aims to classify clusters of young children according to their eating habits and identify the features of each cluster as they relate to childhood obesity.

Methods: A total of 1,280 children were selected from the Panel Study on Korean Children. In addition to data on their eating habits (eating speed, meal time regularity, food amount consistency, and balanced eating), we also obtained data on sleep hours per day, outdoor activity hours per day, and body mass index at 5 years old. A cluster analysis was performed based on the children's eating habits using unsupervised machine learning methods. Analysis of variance and chi-square analyses were conducted to identify differences in the children's body mass index at 6 years old and the characteristics of their parents and family by cluster.

Results: Four clusters were identified based on the children's eating habits. Cluster 1 was characterized by a fast eating speed (fast eaters), cluster 2 was characterized by a slow eating speed (slow eaters), cluster 3 was characterized by irregular eating habits (poor eaters), and cluster 4 was characterized by a balanced diet and regular meal times and consistent food amounts (healthy eaters). When the clusters were compared, body mass index (P<.001), sleep duration (P=.012), and mother's education level (P=.027) differed significantly. Fast eaters tended to have the highest body mass index at both ages, while slow eaters tended to have the lowest body mass index. Fast eaters tended to sleep longer than slow eaters.

Conclusions: Efforts to establish healthy eating habits in early childhood may potentially contribute to the prevention of obesity in children. Future research is needed to take multidimensional lifestyles into account, such as children's sleep patterns, activity levels, and their mother's education level, to better understand childhood obesity.

(JMIR Preprints 04/08/2023:51581)
DOI: https://doi.org/10.2196/preprints.51581

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Comparison of Clusters by Eating Habits between Five and Six Years Old on Korean Children: A Panel Survey Analysis

Abstract

Background: Childhood obesity has emerged as a major health issue due to rapid growth in the prevalence of obesity among young children worldwide. Establishing healthy eating habits and lifestyles in early childhood may help children gain appropriate weight and further improve their health outcomes later in life.

Objectives: This study aims to classify clusters of young children according to their eating habits and identify the features of each cluster as they relate to childhood obesity.

Methods: A total of 1,280 children were selected from the Panel Study on Korean Children. Data on their eating habits (eating speed, meal time regularity, food amount consistency, and balanced eating), sleep hours per day, outdoor activity hours per day, and body mass index were obtained. A cluster analysis was performed on the children's eating habits using K-means methods. Analysis of variance and chi-square analyses were conducted to identify differences in the children's body mass index, sleep hours, physical activity, and the characteristics of their parents and family by cluster.

Results: At both ages, four clusters were identified based on the children's eating habits. Cluster 1 was characterized by a fast eating speed (fast eaters), cluster 2 by a slow eating speed (slow eaters), cluster 3 by irregular eating habits (poor eaters), and cluster 4 by a balanced diet and regular meal times and consistent food amounts (healthy eaters). Slow eaters tended to have the lowest body mass index ($P < .001$) and a low proportion of overweight and obesity at five years old ($P = .03$) and a year later ($P = .005$). There was also a significant difference in sleep time ($P = .01$) and mother's education level ($P = .03$) at five years old. There was a significant difference in sleep time ($P=.03$) and the father's education level ($P = .02$) at six years old.

Conclusions: Efforts to establish healthy eating habits in early childhood may contribute to the prevention of obesity in children. Specifically, providing dietary guidance on a child's eating speed can help prevent childhood obesity. This research suggests that lifestyle modification could be a viable target to decrease the risk of childhood obesity and promote the development of healthy children. Additionally, we propose that future studies examine long-term changes in obesity resulting from lifestyle modifications in children from families with low educational levels.

Keywords: pediatric obesity; preschool child; healthy lifestyle; cluster analysis; unsupervised machine learning.

Introduction

Childhood obesity has emerged as a major health issue due to rapid growth in the prevalence of obesity among young children and the higher risk of developing cardiovascular and metabolic diseases in adulthood [1,2]. To address these health problems, childhood obesity has been studied for decades, and great efforts have been made to identify and characterize potential predictors of childhood obesity [3]. However, more studies are needed to understand which factors are involved and their complex relationship with the development of childhood obesity [4].

Obesity can be caused by a combination of biological factors such as an individual's genes, insulin resistance, disease, and metabolic processes as well as socioeconomic factors such as the surrounding family and environment leading to obesity-related behaviors [5-7]. Although, fundamentally, excessive energy due to an imbalance between energy intake and consumed energy is known to cause fat formation and obesity, Davison and Birch [8] explain the various causes of childhood obesity as a micro and macro system surrounding the child and provide evidence of the need for great efforts to change behavior to improve children's health.

Eating habits affect dietary intake and obesity through various behaviors such as meal frequency, amount, speed, and snacking habits [9]. A prospective cohort study in which eating habits were measured repeatedly confirmed that there were individual differences in the development of food enjoyment and satiety responsiveness, which affect eating habits after the age of four. These results suggest that eating habits are dynamic behaviors in the first years of life and may change beyond preschool age [10]. The GUSTO study measured the eating habits of five- and six-year-olds and found that obesity and overweight in children were related to rapid eating speed [11]. Therefore, understanding the early life factors that influence these behaviors may help identify areas for intervention to curb the progression of overweight and obesity in children [12].

In terms of obesity prevention, the period of childhood before the age of five is very important as an opportunity to establish new behaviors rather than changing existing behaviors that have become entrenched in adulthood, which presents a difficult challenge [13]. Children's eating habits begin with solid foods from three to six months of age. From that time until the age of five, preschool children learn autonomous eating habits from their parents and form eating habits based on their own preferences and previous experiences [14]. Additionally, preschool children under the age of five who are obese are more likely than children with normal weight to become overweight during adolescence and are five times more likely to become obese as adults. Thus, prevention through healthy lifestyle habits early in childhood is important [15]. The importance of these early childhood lifestyle habits is highlighted by the World Health Organization’s guidelines for children's health, which also discuss the importance of forming lifestyle habits in children before the age of five [16].

Establishing a healthy lifestyle early in life is important to improve health outcomes later [17]. A recent literature review on childhood obesity revealed that, to prevent childhood obesity, changes need to be made in children’s overall lifestyle, including their daily living habits, rather than limiting management to food intake [18,19]. However, the number of studies generally recommend limiting the intake of high-calorie foods, sugary drinks, and fast foods and eating more fruit and vegetables to prevent childhood obesity [20-22]. As an eating practice guideline, dietary habits, such as eating breakfast, balanced eating, and eating slowly, are recommended during mealtimes, but studies on the relationship between these eating habits and early childhood obesity are limited [23,24]. Additionally, previous obesity research using machine learning explored the relationship between demographic factors and some behaviors and childhood obesity but had limitations due to single cross-sectional methods and small sample sizes [25,26]. Therefore, this study is designed to identify characteristic patterns of preschool children's eating habits using unsupervised machine learning techniques and to determine the impact of these eating habits on children's body mass index (BMI).

Our results provide evidence that can guide healthy eating habits to prevent childhood obesity.

Methods

Study Design and Data

This study utilized data from the Panel Study on Korean Children (PSKC), which was designed to follow a sample of children from 2008 to 2027 to confirm the impact of families and communities on children's growth and development. The PSKC is a nationally representative sample using stratified sampling that considers all the regions in South Korea. For this panel survey, parents with children born between April and July 2008 were recruited from 30 hospitals. In the first survey, a total of 2,150 parents participated in face-to-face interviews and completed a self-administered questionnaire [27]. However, only 1,280 children were included in this study because they had both the sixth and seventh surveys of the PSKC. For this study, the sixth dataset (at five years of age) and seventh dataset (at six years of age) were obtained for the data analysis after excluding missing and incomplete data (Appendix 1). The data used for this study is considered representative sample to national data in terms of the national demographics (male 50.7%, female 49.3%) and prevalence of childhood obesity (overweight 9.5%, obese 4.2%) [28].

Measurements

Eating Habits

Eating habits were assessed based on four questions that mothers (or fathers) were asked to answer: "Is your child's eating speed fast?", "Does your child have meals at regular times?", "Is the amount of food your child eats consistent?", and "Does your child eat all kinds of food?" Responses to each question were assessed using a five-point Likert scale ranging from "not at all" to "agree very strongly." A higher score indicated a greater tendency in the diet habit.

Body Mass Index

Obesity status, the primary outcome of this study, was defined according to BMI, which was calculated using the children's weight and height [29]. The categories, such as normal, overweight, and obese, were defined based on the Korean child growth chart: children in the 85 to 95 percentile were categorized as overweight, and those over the 95 percentile were categorized as obese [30,31].

Physical Activity

For the children's activity levels, we used hours spent in outdoor activity as perceived by their mothers. They calculated the average number of hours their child spent daily on outdoor activities.

Sleep Duration

For the children's sleep hours, we used the average amount of sleep time as perceived by their mothers. The child's average sleep time at night was calculated as the difference between the mother's reported bedtime and wake-up time.

Characteristics of Parents and Family

Parental age, education level, and employment status were obtained as parent characteristics; the number of family members and family income (Korean won per month) were obtained as family characteristics.

Ethical Approval

This study was approved by the Hospital Ethics Committee, Seoul, South Korea (No. 4-2023-0418). The PSKC database was created with the voluntary consent of participants to investigate the growth

and development of Korean children. If a participant decides to withdraw, they are excluded from the database. Virtual anonymized datasets were obtained after obtaining consent from PSKC in relation to the data. This study rigorously followed the guidelines recommended by the PSKC [32].

Statistical Analyses

All the continuous variables were tested for normality using the Shapiro-Wilk and Kolmogorov tests. The Shapiro-Wilk statistic was significant ($P < .001$), and the plots (regression of standardized residuals) showed no clear signs of violating the normality assumption [33].

Cluster analyses were performed in R (version 4.1.3) using the packages “tidyverse,” “cluster,” “factoextra,” and “NbClust.” Clustering is an unsupervised machine learning technique to find natural groupings of participants based on a dataset’s inherent structure. To identify the clusters, four eating habits (eating speed, meal time regularity, food amount consistency, and balanced eating) were used as the input variables. For the ordinal variables measured on a five-point Likert scale, we scaled by considering the means and standard deviations of the variables [26]. Principal Component Analysis was used to check the data distribution and independence of four eating habits. Before the dataset was considered significantly clusterable, the Hopkins statistic was applied iteratively using a threshold of 0.5, and the dataset was confirmed to be above the threshold. The clustering analysis was performed by applying two hierarchical clustering methods (agglomeration and division) and Ward’s approach based on Euclidean distance and k-means [34]. We used the NbClust R package to explore the optimal number of clusters in our dataset by varying all combinations of cluster number, distance measure, and clustering method and considered the Elbow method (k = 4) and Scott index (k = 4) for optimal cluster selection [35] (Appendix 2). Finally, the number of clusters (k = 4) was selected by visually inspecting the data (clusters 1, 2, 3, and 4). After selecting the number of clusters, clusters were formed by repeating the K-means algorithm, which is most commonly used in unsupervised machine learning techniques, until the center value of the cluster did not change. Once the clusters were identified [35], a radar chart was created to explore the functionality of the final clusters (Figure 1).

[Insert Figure 1 here]

One-way analysis of variance with Bonferroni post-hoc comparison and a chi-square test were used to assess the group differences [36]. The power of this study was calculated using G*power (version 3.1) with a 95% degree of confidence, and the number of participants and study design were considered through a comparison of the differences between clusters. Statistical significance was defined as $P < .05$ (two-sided).

Results

Children Characteristics

Of those analyzed, 50.7% were boys, and the children’s mean birth weight was 3.26 kg (SD = 0.41). The average baseline BMI was 15.99 (1.60) at five years old and 16.20 (2.01) at six years old. At five years old, the children's average time spent on outdoor activities was 1.14 hours per day (0.81), and the average sleep duration per day was 9.87 hours (0.73). The children's average time spent on outdoor activities was 1.08 hours per day (0.71), and the average sleep duration per day was 9.76 hours (0.68) at six years old.

A bachelor's degree was the most prevalent education level in both mothers (37.89%) and fathers (43.13%). Most of the fathers (96.09%) worked, and the average family income was 4,275,100 won

per month (205.19) (Appendix 3).

Cluster Developed by Eating Habits

The analysis identified four clusters, and their characteristics are similar on a radar chart (Figure 1). Cluster 1 (fast eaters) is characterized by a high eating speed and represents 512 five- and 440 six-year-old children; cluster 2 (slow eaters) represents 293 five- and 415 six-year-old children with a slow eating speed. Cluster 3 (poor eaters) represents 283 five- and 243 six-year-old children with irregular meal times, inconsistent food amounts, and imbalanced eating habits, and cluster 4 (healthy eaters) represents 192 five- and 182 six-year-old children with regular meal times, consistent food amounts, and balanced eating (Table 1).

[Insert Table 1 here]

Cluster Changes from Five to Six Years of Age

Changes in clusters according to children's eating habits are shown in Figure 2. Of the total 1,028 children, 553 (53.8%) remained in the same eating habits cluster as classified at age five years; 229 (44.7%) of 512 in the fast eater group, 154 (52.6%) of 293 in the slow eater group, 108 (38.2%) in the poor eater group, and 62 (32.3%) in the healthy eater group remained in the same cluster a year later.

[Insert Figure 2 here]

Characteristic Differences by Clusters at Five Years of Age

Among children’s characteristics, there was a significant difference in BMI at age five between groups ($P < .001$). Fast eaters also had the highest BMI at age five (mean = 16.17); slow eaters had the lowest BMI (mean = 15.59). The proportion of children with obesity differed significantly between groups ($P = .03$). A higher proportion of children with obesity, based on BMI at age five, was reported among poor eaters (5.7%) and fast eaters (5.5%). There was a significant difference in sleep duration; fast eaters were associated with longer sleep duration (9.93 hours per day) than slow eaters ($P = .005$). Among parental and family characteristics, healthy eaters had a higher proportion of mothers with master's degrees or higher, and poor eaters had a higher proportion of mothers who were high school graduates or lower ($P = .03$). There were no significant differences in the time children spent outdoors, family income, and parent's employment status (Table 2).

[Insert Table 2 here]

Characteristic Differences by Clusters at Six Years of Age

Among children's characteristics, there was a significant difference between groups in BMI at age six ($P < .001$). Fast eaters also had the highest BMI at age six (mean = 16.55); slow eaters had the lowest BMI (mean = 15.85). The proportion of children with obesity differed significantly between groups ($P = .01$). A higher proportion of children with obesity, based on BMI at age six, was reported among fast eaters (9.1%) and poor eaters (8.8%). There was a significant difference in sleep duration; healthy eaters were associated with longer sleep duration (9.89 hours per day) than fast eaters ($P = .03$). Among parental and family characteristics, healthy eaters had a higher proportion of fathers with master's degrees or higher, and poor eaters had a higher proportion of fathers who were high school graduates or lower ($P = .03$). There were no significant differences in the time children spent outdoors, family income, and parents' employment status (Table 3).

[Insert Table 3 here]

Discussion

Using a nationally representative sample, we identified four distinct clusters based on the eating habits of five- and six-year-old children. The same children's eating habits showed a pattern of four clusters a year later. However, in approximately half of the children, individual children changed their eating habit cluster after one year in this study, providing valuable insight into the timing of early obesity management [37]. Additionally, the higher proportion of overweight and obesity and higher BMI in children who eat quickly indicate that fast eating is associated with obesity. Five-year-old children who are fast eaters need age-appropriate training to reduce their eating speed. Importantly, strategies to prevent a progression from overweight to obesity in young children should be developed to improve children's overall health status.

While a few studies have attempted to identify the relationship between eating habits and obesity in young children [4,23,38,39], none of them investigated eating habits concurrently, such as eating speed, balanced eating, meal time regularity, and food amount consistency. In this study, we found that a large number of young children fell into the category of fast eaters and had a higher BMI. This relationship between fast eating habits and obesity can be explained by the mechanism that fast eating lowers satiety and consequently increases food intake by delaying the effects of brain signals and hormones [40]. The results of this study also suggest childhood obesity could be prevented by increasing eating time [39]. Regarding another eating habit related to childhood obesity, a recent systematic review identified meal time as a mechanism that explains obesity by affecting changes in metabolic efficiency, hormones, and gut microbiota throughout the day [14]. Paoli et al. emphasized the importance of regular eating times for obesity prevention through the regularity of fasting periods between meals [41].

Regarding the relationship between sleep duration and childhood obesity, insufficient sleep could contribute to the development of obesity through appetite, diet, and daytime activity levels [43,44]. These studies did not support previous reports of late bedtimes and short sleep duration in children with obesity [42]. However, in this study, sleep duration per cluster was more than 9 hours, so all of the children had enough sleep, which limits exploration of the relationship between sleep duration and obesity in our study. Additional research on sleep and childhood obesity is recommended.

Among the risk factors for childhood obesity, a more important explanatory factor is sedentary time, such as TV watching time, rather than outdoor activity [45]. Similarly, this study found no difference in outdoor activity levels between the groups classified based on eating habits. The relationship between childhood obesity and physical activity levels should be explored by considering various activities, such as sedentary time and indoor activities, in addition to outdoor activities.

Besides children's sleep duration and activity levels, the parents' education level differed among the clusters. The proportion of parents with a high school diploma or lower was higher in the group of poor eaters than in the other eating groups. These results are similar to those of previous studies showing that mothers of children with overweight or obesity had a lower education level [4]. This suggests that parents' level of education is a factor related to the development of childhood obesity. However, the single influence of the mother or father by age, rather than both parents, is thought to account for differences in parental influence as the child ages and requires further research [46]. The prevalence of childhood obesity is known to be high in low-income households and communities with low socioeconomic status, and the relationship between childhood obesity and families' economic status has been well documented in large samples in several countries [43,47,48]. However, family income in this study did not differ between the clusters, which suggests that primary caregiver education is the key factor in forming eating habits to consider for the prevention of obesity in children [44].

Limitations

This study has several strengths and limitations that should be noted. Although the individual clusters had different BMI tendencies, the inclusion of only eating habit variables in the cluster analysis could limit our understanding of the development of childhood obesity since it omits interrelated variables such as physical activity and sleep. In addition, the results should be interpreted with caution because each eating habit were measured using a single item based on a Likert scale. However, we found evidence for the impact of dietary guidelines to prevent obesity in young children, including specific eating habits. Another limitation of this study was the reliance on parental reports. Nevertheless, the study is meaningful in that it used panel data that are representative longitudinal data of a country's child population, and the derived results used machine learning techniques to solve complex phenomena targeting a relatively large sample of children.

Conclusions

Our results show that eating habits, such as eating speed, regularity of meal times, meal amount consistency, and balanced eating habits, can be considered risk factors for developing childhood obesity. In addition, changed clusters by eating habits within two years in children highlights the need for early childhood obesity management. Besides eating habits, children's sleep duration and maternal education levels differed significantly across the clusters. These findings suggest that a modification in lifestyle could be a good target to decrease the risk of childhood obesity and develop healthy children. In addition, we also propose that future studies examine long-term changes in obesity with lifestyle modification in children from families with low educational levels.

Acknowledgements

This study was supported by funding from the College of Nursing, Yonsei University (6-2022-0036).

Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

HML and HL conceptualized the study and contributed to the study’s design. HML worked on the data curation and analysis. HML and HL drafted the manuscript with critical input. All the authors approved the final version of the manuscript and agreed to its publication.

Conflicts of Interest

The authors declare there are no conflicts of interest regarding the publication of this paper.

References

1. Lobstein T, Jackson-Leach R, Moodie ML, Hall KD, Gortmaker SL, Swinburn BA, James WPT, Wang Y, McPherson K. Child and adolescent obesity: part of a bigger picture. The Lancet 2015;385(9986):2510-2520. doi:10.1016/S0140-6736(14)61746-3.
2. Cunningham SA, Hardy ST, Jones R, Ng C, Kramer MR, Narayan K. Changes in the incidence of childhood obesity. Pediatrics 2022;150(2). doi:10.1542/peds.2021-053708.
3. Mura Paroche M, Caton SJ, Vereijken CM, Weenen H, Houston-Price C. How infants and young children learn about food: A systematic review. Frontiers in Psychology

2017;8:1046. doi:10.3389/fpsyg.2017.01046.
4. Wang Q, Yang M, Deng X, Wang S, Zhou B, Li X, Shi J, Zhang Z, Niu W. Explorations on risk profiles for overweight and obesity in 9501 preschool-aged children. Obesity Research & Clinical Practice 2022;16(2):106-114. doi:10.1016/j.orcp.2022.02.007.
5. Ludwig DS, Apovian CM, Aronne LJ, Astrup A, Cantley LC, Ebbeling CB, Heymsfield SB, Johnson JD, King JC, Krauss RM. Competing paradigms of obesity pathogenesis: energy balance versus carbohydrate-insulin models. European journal of clinical nutrition 2022;76(9):1209-1221.
6. Albuquerque D, Nóbrega C, Manco L, Padez C. The contribution of genetics and environment to obesity. British medical bulletin 2017;123(1):159-173.
7. Scaglioni S, De Cosmi V, Ciappolino V, Parazzini F, Brambilla P, Agostoni C. Factors influencing children's eating behaviours. Nutrients 2018;10(6):706.
8. Davison KK, Birch LL. Childhood overweight: a contextual model and recommendations for future research. Obesity reviews 2001;2(3):159-171.
9. Agostoni C, Braegger C, Decsi T, Kolacek S, Koletzko B, Mihatsch W, Moreno LA, Puntis J, Shamir R, Szajewska H. Role of dietary factors and food habits in the development of childhood obesity: a commentary by the ESPGHAN Committee on Nutrition. Journal of pediatric gastroenterology and nutrition 2011;52(6):662-669.
10. Derks IP, Bolhuis K, Sijbrands EJ, Gaillard R, Hillegers MH, Jansen PW. Predictors and patterns of eating behaviors across childhood: Results from The Generation R study. Appetite 2019;141:104295.
11. Quah PL, Fries LR, Chan MJ, Fogel A, McCrickerd K, Goh AT, Aris IM, Lee YS, Pang WW, Basnyat I. Validation of the Children's Eating Behavior Questionnaire in 5 and 6 year-old children: the GUSTO Cohort Study. Frontiers in Psychology 2019;10:824.
12. Moreno LA, Rodriguez G. Dietary risk factors for development of childhood obesity. Current Opinion in Clinical Nutrition & Metabolic Care 2007;10(3):336-341.
13. Natale RA, Messiah SE, Asfour L, Uhlhorn SB, Delamater A, Arheart KL. Role modeling as an early childhood obesity prevention strategy: effect of parents and teachers on preschool children's healthy lifestyle habits. Journal of Developmental & Behavioral Pediatrics 2014;35(6):378-387.
14. Davis R, Rogers M, Coates AM, Leung GK, Bonham MP. The impact of meal timing on risk of weight gain and development of obesity: a review of the current evidence and opportunities for dietary intervention. Current Diabetes Reports 2022;22(4):147-155. doi:10.1007/s11892-022-01457-0.
15. Singhal A. Obesity in toddlers and young children: causes and consequences. Building Future Health and Well-Being of Thriving Toddlers and Young Children 2020;95:41-51.
16. Willumsen J, Bull F. Development of WHO guidelines on physical activity, sedentary behavior, and sleep for children less than 5 years of age. Journal of physical activity and health 2020;17(1):96-100.
17. Mihrshahi S, Baur LA. What exposures in early life are risk factors for childhood obesity? Journal of paediatrics and child health 2018;54(12):1294-1298. doi:10.1111/jpc.14195.
18. Pereira AR, Oliveira A. Dietary interventions to prevent childhood obesity: A literature review. Nutrients 2021;13(10):3447. doi:10.3390/nu13103447.
19. Tyson N, Frank M. Childhood and adolescent obesity definitions as related to BMI, evaluation and management options. Best practice & research Clinical obstetrics & gynaecology 2018;48:158-164. doi:10.1016/j.bpobgyn.2017.06.003.
20. Smethers AD, Roe LS, Sanchez CE, Zuraikat FM, Keller KL, Rolls BJ. Both increases and decreases in energy density lead to sustained changes in preschool children's energy intake over 5 days. Physiology & behavior 2019;204:210-218.

doi:10.1016/j.physbeh.2019.02.042.
21. Poorolajal J, Sahraei F, Mohamdadi Y, Doosti-Irani A, Moradi L. Behavioral factors influencing childhood obesity: a systematic review and meta-analysis. Obesity research & clinical practice 2020;14(2):109-118. doi:10.1016/j.orcp.2020.03.002.
22. Liberali R, Kupek E, Assis MAAd. Dietary patterns and childhood obesity risk: a systematic review. Childhood Obesity 2020;16(2):70-85. doi:10.1089/chi.2019.0059.
23. Fogel A, Goh AT, Fries LR, Sadananthan SA, Velan SS, Michael N, Tint M-T, Fortier MV, Chan MJ, Toh JY. Faster eating rates are associated with higher energy intakes during an ad libitum meal, higher BMI and greater adiposity among 4· 5-year-old children: Results from the Growing Up in Singapore Towards Healthy Outcomes (GUSTO) cohort. British Journal of Nutrition 2017;117(7):1042-1051. doi:10.1017/S0007114517000848.
24. Verduci E, Di Profio E, Fiore G, Zuccotti G. Integrated approaches to combatting childhood obesity. Annals of Nutrition and Metabolism 2022;78(2):8-19.
25. Bel-Serrat S, Ojeda-Rodríguez A, Heinen MM, Buoncristiano M, Abdrakhmanova S, Duleva V, Farrugia Sant'Angelo V, Fijałkowska A, Hejgaard T, Huidumac C. Clustering of multiple energy balance-related behaviors in school children and its association with overweight and obesity—WHO European Childhood Obesity Surveillance Initiative (COSI 2015–2017). Nutrients 2019;11(3):511. doi:10.3390/nu12051288.
26. Leis R, Jurado-Castro JM, Llorente-Cantarero FJ, Anguita-Ruiz A, Iris Rupérez A, Bedoya-Carpente JJ, Vázquez-Cobela R, Aguilera CM, Bueno G, Gil-Campos M. Cluster analysis of physical activity patterns, and relationship with sedentary behavior and healthy lifestyles in prepubertal children: Genobox cohort. Nutrients 2020;12(5):1288. doi:10.3390/nu12051288.
27. Kim S, Chung I-J, Lee J. Structural model of parenting dimension, media usage type and body mass index in Korean preschool children. Children and Youth Services Review 2017. doi:10.1016/j.childyouth.2017.06.028.
28. Park HK, Seo JY, Jung HW, Lim JS. Prevalence and trends in obesity and severe obesity in Korean children and adolescents, 2007–2020: A population-based study. Pediatrics International 2023;65(1):e15472.
29. Shields M, Tremblay MS. Canadian childhood obesity estimates based on WHO, IOTF and CDC cut-points. International Journal of Pediatric Obesity 2010;5(3):265-273. doi:10.3109/17477160903268282.
30. Kim JH, Yun S, Hwang S-s, Shim JO, Chae HW, Lee YJ, Lee JH, Kim SC, Lim D, Yang SW. The 2017 Korean National Growth Charts for children and adolescents: development, improvement, and prospects. Korean journal of pediatrics 2018;61(5):135. doi:10.3345/kjp.2018.61.5.135.
31. Seo JW. Obesity in children and adolescents. Clinical and Experimental Pediatrics 2009;52(12):1311-1320. doi:10.3345/kjp.2009.52.12.1311
32. Korea Institute of Child Care and Education. Panel Study on Korean Children (PSKC) data use manual for 1st-7th study. Available: https://panel.kicce.re.kr/pskc/board/view.do?menu_idx=43&board_idx=33366&manage_idx=27&old_menu_idx=0&old_manage_idx=0&old_board_idx=0&group_depth=0&parent_idx=0&group_idx=0&group_ord=0&viewMode=NORMAL&search_type=title&search_text=&rowCount=10&viewPage=1. Accessed August 19 2022.
33. Bischoff W. A functional central limit theorem for regression models. The Annals of Statistics 1998;26(4):1398-1410. doi:10.1214/aos/1024691248.
34. James G, Witten D, Hastie T, Tibshirani R. An introduction to statistical learning: Springer; 2013.
35. Cai K, Rodavia MR. K-Means Cluster Analysis Based on Consumer Behavior. 2022 4th

International Conference on Artificial Intelligence and Advanced Manufacturing (AIAM): IEEE; 2022. p.143-146.
36. Lee SW. Methods for testing statistical differences between groups in medical research: statistical standard and guideline of Life Cycle Committee. Life Cycle 2022;2.
37. Black MM, Walker SP, Fernald LC, Andersen CT, DiGirolamo AM, Lu C, McCoy DC, Fink G, Shawar YR, Shiffman J. Early childhood development coming of age: science through the life course. The Lancet 2017;389(10064):77-90.
38. Okubo H, Miyake Y, Sasaki S, Tanaka K, Hirota Y. Rate of eating in early life is positively associated with current and later body mass index among young Japanese children: the Osaka Maternal and Child Health Study. Nutrition Research 2017;37:20-28. doi:10.1016/j.nutres.2016.11.011.
39. Faith MS, Diewald LK, Crabbe S, Burgess B, Berkowitz RI. Reduced eating pace (RePace) behavioral intervention for children prone to or with obesity: does the turtle win the race? Obesity 2019;27(1):121-129. doi:10.1002/oby.22329.
40. Robinson E, Almiron-Roig E, Rutters F, de Graaf C, Forde CG, Tudur Smith C, Nolan SJ, Jebb SA. A systematic review and meta-analysis examining the effect of eating rate on energy intake and hunger. The American journal of clinical nutrition 2014;100(1):123-151. doi:10.3945/ajcn.113.081745.
41. Paoli A, Tinsley G, Bianco A, Moro T. The influence of meal frequency and timing on health in humans: the role of fasting. Nutrients 2019;11(4):719. doi:10.3390/nu11040719.
42. Kaar JL, Schmiege SJ, Vadiveloo M, Simon SL, Tovar A. Sleep duration mediates the relationship between health behavior patterns and obesity. Sleep Health 2018;4(5):442-447. doi:10.1016/j.sleh.2018.07.004.
43. YARDIM M, ÖZCEBE L, ARAZ Ö, ÜNER S, Li S, ÜNLU H, Arslan U, Bilir N, Huang T. Prevalence of childhood obesity and related parental factors across socioeconomic strata in Ankara, Turkey. Eastern Mediterranean Health Journal 2019;25(6). doi:10.26719/emhj.18.052.
44. Wu XY, Ohinmaa A, Maximova K, Veugelers PJ. The importance of eating patterns for health-related quality of life among children aged 10–11 years in Alberta of Canada. Scientific Reports 2022;12(1):20885. doi:10.1038/s41598-022-23707-7.
45. Saldanha-Gomes C, Marbac M, Sedki M, Cornet M, Plancoulaine S, Charles M-A, Lioret S, Dargent-Molina P. Clusters of diet, physical activity, television exposure and sleep habits and their association with adiposity in preschool children: the EDEN mother-child cohort. International Journal of Behavioral Nutrition and Physical Activity 2020;17(1):1-13. doi:10.1186/s12966-020-00927-6.
46. Cabrera NJ, Fagan J, Wight V, Schadler C. Influence of mother, father, and child risk on parenting and children's cognitive and social behaviors. Child development 2011;82(6):1985-2005.
47. Fismen AS, Buoncristiano M, Williams J, Helleve A, Abdrakhmanova S, Bakacs M, Bergh IH, Boymatova K, Duleva V, Fijałkowska A. Socioeconomic differences in food habits among 6-to 9-year-old children from 23 countries—WHO European Childhood Obesity Surveillance Initiative (COSI 2015/2017). Obesity Reviews 2021;22:e13211. doi:10.1111/obr.13211.
48. Orden AB, Lamarque MS, Apezteguía MC. Trend in childhood obesity reflects socioeconomic status in Argentina. Annals of Human Biology 2019;46(7-8):531-536. doi:10.1080/03014460.2019.1694070.

Abbreviations

BMI: Body Mass Index

PSKC: Panel Study on Korean Children

Table 1. Comparison of the children's eating habits by cluster (N = 1,280)

Eating habit	At 5 years old				At 6 years old			
	Fast eater (N = 512)	Slow eater (N = 293)	Poor eater (N = 283)	Healthy eater (N = 192)	Fast eater (N = 442)	Slow eater (N = 415)	Poor eater (N = 241)	Healthy eater (N = 182)
Eating speed	3.24 (0.48)	1.94 (0.50)	2.72 (0.74)	3.01 (0.73)	3.47 (0.59)	2.48 (0.70)	2.60 (0.72)	3.40 (0.96)
Regularity of mealtime	3.91 (0.39)	3.97 (0.50)	2.98 (0.61)	4.98 (0.14)	3.95 (0.29)	4.19 (0.39)	3.25 (0.72)	4.92 (0.28)
Consistency of food amount	3.85 (0.38)	3.72 (0.50)	2.76 (0.53)	4.73 (0.45)	3.87 (0.36)	4.07 (0.32)	2.96 (0.60)	4.84 (0.37)
Balanced eating	3.65 (0.66)	2.76 (0.82)	2.65 (0.82)	4.00 (0.89)	4.03 (0.51)	2.79 (0.84)	2.69 (0.84)	4.38 (0.71)

Values are provided as mean (SD)

Table 2. Differences in characteristics by cluster at five years of age (N = 1,280)

Variable	Fast eater (N = 512)[a]	Slow eater (N = 293)[b]	Poor eater (N = 283)[c]	Healthy eater (N = 192)[d]	*P* value *	Post hoc test
Characteristics of Child						
Sex						
Male	261 (51%)	146 (49.8%)	145 (51.2%)	97 (50.5%)	.987	
Female	251 (49%)	147 (50.2%)	138 (48.8%)	95 (49.5%)		
Birth weight (kg)	3.28 (0.40)	3.22 (0.39)	3.26 (0.42)	3.28 (0.42)	.179	
BMI at 5 years old (kg/m^2)	16.17 (1.63)	15.59 (1.31)	16.03 (1.76)	16.06 (1.61)	<.001	a,c,d > b
Overweight	53 (10.4%)	21 (7.2%)	25 (8.8%)	23 (12.0%)	.028	
Obese	28 (5.5%)	4 (1.4%)	16 (5.7%)	6 (3.1%)		
Physical activity (hour/day)	1.16 (0.83)	1.17 (0.81)	1.06 (0.81)	1.13 (0.75)	.365	
Sleep duration (hour/day)	9.93 (0.71)	9.79 (0.73)	9.79 (0.74)	9.93 (0.76)	.012	a > b
Characteristics of Mother						
Age	35.9 (3.46)	36.0 (3.43)	35.9 (3.74)	36.3 (3.42)	.772	
Education level						
High school or less	152 (29.7%)	78 (26.6%)	94 (33.2%)	50 (26%)	.027	
College degree	132 (25.8%)	96 (32.8%)	78 (27.6%)	50 (26%)		
Bachelor degree	210 (41.0%)	99 (33.8%)	100 (35.3%)	76 (39.6%)		
Master’s degree or higher	18 (3.5%)	20 (6.8%)	11 (3.9%)	16 (8.3%)		
Employment status						

Table 2. Differences in characteristics by cluster at five years of age (N = 1,280) continued

Variable	Fast eater (N = 512)[a]	Slow eater (N = 293)[b]	Poor eater (N = 283)[c]	Healthy eater (N = 192)[d]	*P* value *	Post hoc test
Employed	206 (40.2%)	124 (42.3%)	111 (39.2%)	97 (50.5%)	.063	
Unemployed	306 (59.8%)	169 (57.7%)	172 (60.8%)	95 (49.5%)		
Characteristics of Father						
Age	38.5 (3.97)	38.9 (3.70)	38.1 (4.0)	38.6 (3.79)	.096	
Education level						
High school or less	146 (28.5%)	74 (25.3%)	83 (29.3%)	44 (22.9%)	.068	
College degree	100 (19.5%)	62 (21.2%)	65 (23%)	28 (14.6%)		
Bachelor degree	213 (41.6%)	136 (46.4%)	105 (37.1%)	98 (51%)		
Master's degree or higher	53 (10.4%)	21 (7.2%)	30 (10.6%)	22 (11.5%)		
Employment status						
Employed	489 (95.5%)	284 (96.9%)	268 (94.7%)	185 (96.4%)	.567	
Unemployed	23 (4.5%)	9 (3.1%)	15 (5.3%)	7 (3.6%)		
Characteristics of Family						
Number of family members	4.29 (0.86)	4.27 (0.77)	4.20 (0.87)	4.25 (0.87)	.384	
Income (10,000 won)	427.48 (227.85)	430.15 (173.44)	418.34 (211.31)	437.08 (175.79)	.794	

Values are provided as mean (SD) or frequency (%)
* *P* value calculated from analysis of variance and chi-square test.
BMI = body mass index

Table 3. Differences in characteristics by cluster at six years of age (N = 1,280)

Variable	Fast eater (N = 440)[a]	Slow eater (N = 415)[b]	Poor eater (N = 243)[c]	Healthy eater (N = 182)[d]	*P* value *	Post hoc test
Characteristics of Child						
Sex						
Male	223 (50.7%)	218 (52.5%)	128 (52.7%)	80 (44%)	.236	
Female	217 (49.3%)	197 (47.5%)	115 (47.3%)	102 (56%)		
Birth weight (kg)	3.28 (0.39)	3.25 (0.40)	3.20 (0.41)	3.32 (0.45)	.023	d > c
BMI at 6 years old (kg/m^2)	16.55 (2.11)	15.85 (1.74)	16.04 (2.01)	16.42 (2.17)	<.001	a > b,c; d > b
Overweight	45 (10.2%)	28 (6.7%)	28 (11.5%)	22 (12.1%)	.005	
Obese	40 (9.1%)	17 (4.1%)	12 (4.9%)	16 (8.8 %)		
Physical activity (hour/day)	1.08 (0.69)	1.05 (0.69)	1.05 (0.74)	1.21 (0.75)	.070	
Sleep duration (hour/day)	9.72 (0.67)	9.77 (0.69)	9.73 (0.69)	9.89 (0.68)	.034	d > a
Characteristics of Mother						
Age	35.8 (3.55)	36.0 (3.43)	35.9 (3.74)	36.3 (3.42)	.772	
Education level						
High school or less	123 (28.0%)	111 (26.7%)	91 (37.4%)	49 (26.9%)	.097	
College degree	127 (28.9%)	112 (27%)	70 (28.8%)	47 (25.7%)		
Bachelor degree	169 (38.4%)	167 (40.2%)	73 (30%)	76 (41.8%)		
Master’s degree or higher	21 (4.8%)	25 (6%)	9 (3.7%)	10 (5.5%)		
Employment status						

Table 3. Differences in characteristics by cluster at six years of age (N = 1,280) continued

Variable	Fast eater (N = 440)[a]	Slow eater (N = 415)[b]	Poor eater (N = 243)[c]	Healthy eater (N = 182)[d]	*P* value *	Post hoc test
Employed	206 (40.2%)	124 (42.3%)	111 (39.2%)	97 (50.5%)	0.213	
Unemployed	306 (59.8%)	169 (57.7%)	172 (60.8%)	95 (49.5%)		
Characteristics of Father						
Age	38.5 (3.97)	38.9 (3.70)	38.1 (4.0)	38.6 (3.79)	.096	
Education level						
High school or less	116 (26.4%)	112 (27%)	81 (33.3%)	38 (20.9%)	.017	
College degree	93 (21.1%)	72 (17.3%)	59 (24.3%)	31 (17%)		
Bachelor degree	185 (42%)	190 (45.8%)	86 (35.4%)	991(50%)		
Master’s degree or higher	46 (10.5%)	41 (9.9%)	17 (7%)	22 (12.1%)		
Employment status						
Employed	489 (95.5%)	284 (96.9%)	268 (94.7%)	185 (96.4%)	.977	
Unemployed	23 (4.5%)	9 (3.1%)	15 (5.3%)	7 (3.6%)		
Characteristics of Family						
Number of family members	4.26 (0.84)	4.25 (0.80)	4.28 (0.96)	4.30 (0.80)	.928	
Income (10,000 won)	440.38 (229.69)	416.80 (165.07)	407.74 (239.91)	440.00 (169.47)	.082	

Values are provided as mean (SD) or frequency (%)
* *P* value calculated from analysis of variance and chi-square test.
BMI = body mass index

Figure 1. Characteristics of the clusters using a radar chart

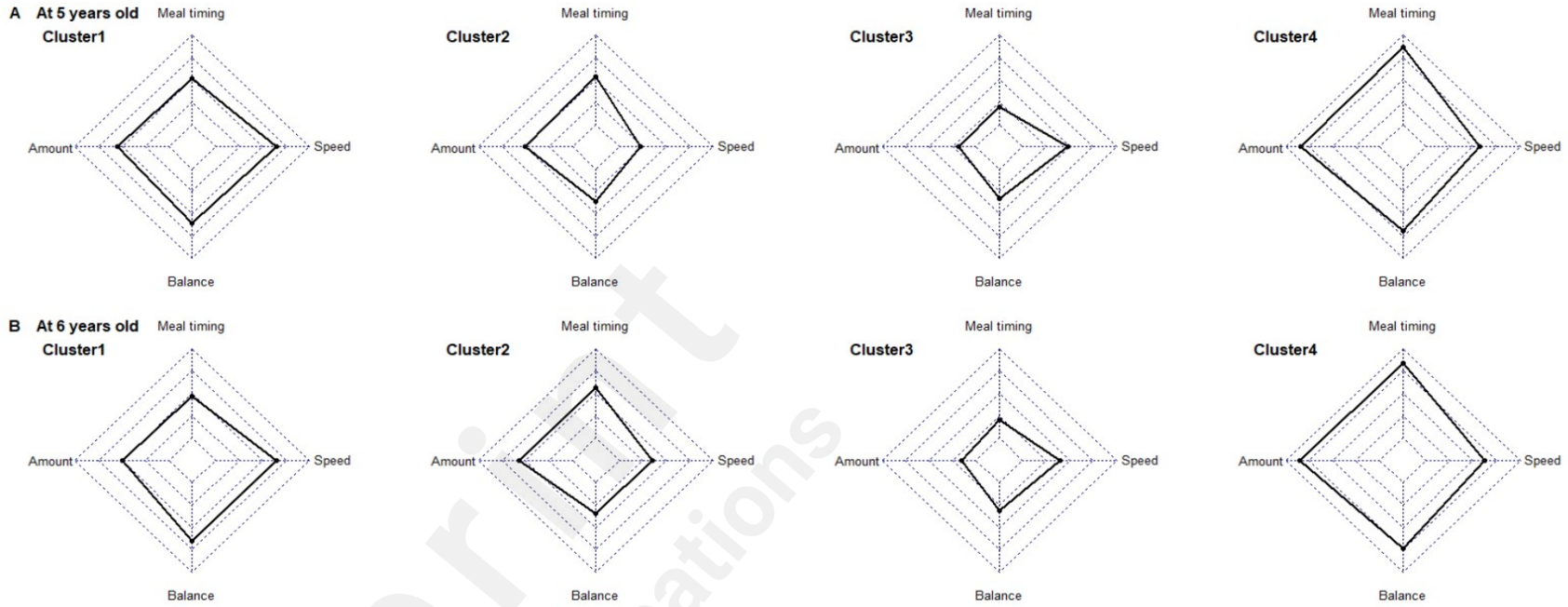


Figure 1 (A) Characteristics of the clusters at 5 years old; (B) Characteristics of the clusters at 6 years old. Individual eating patterns were clustered based on eating speed (Speed), regularity of meal time (Meal timing), balanced eating (Balanced), and consistency of meal amount (Amount). The black line represents the average eating habits of that cluster.

Figure 2. The cluster changes from five to six years of age

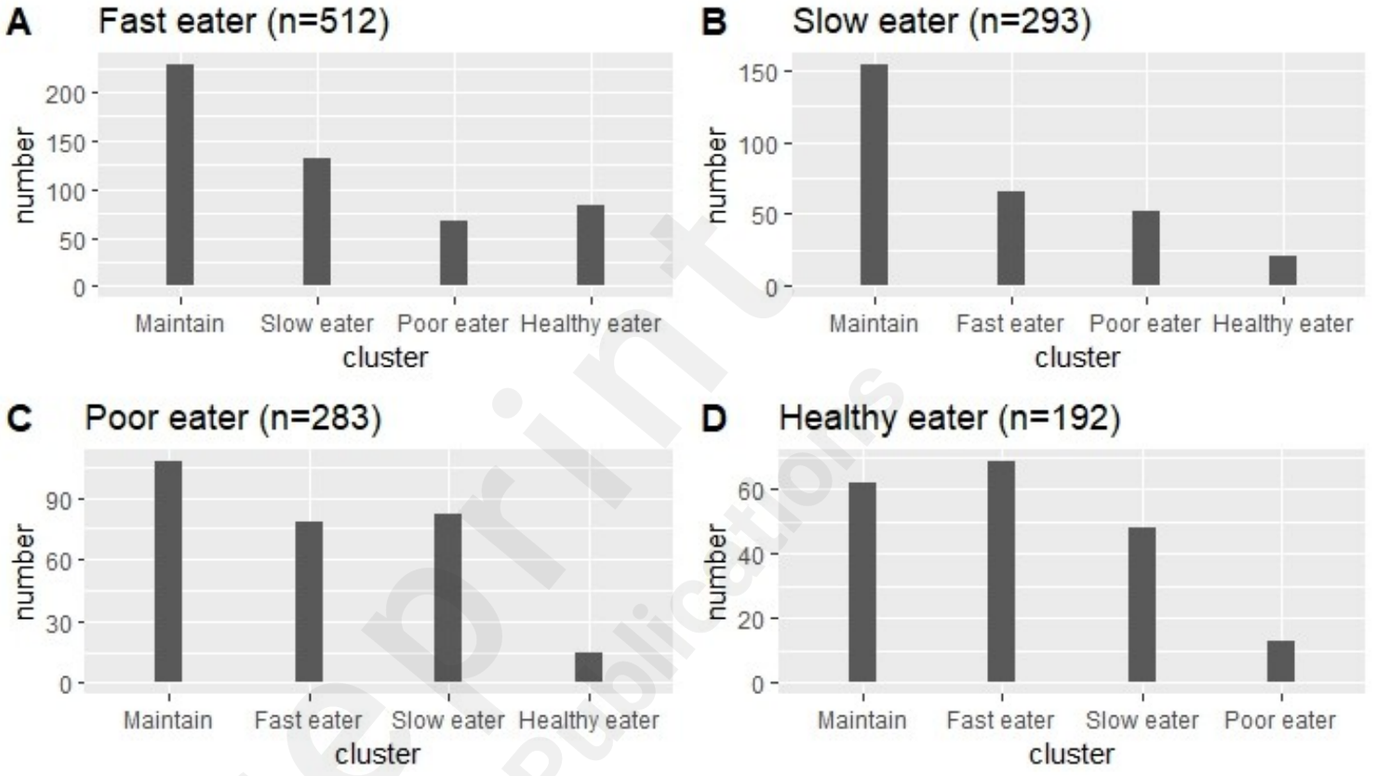
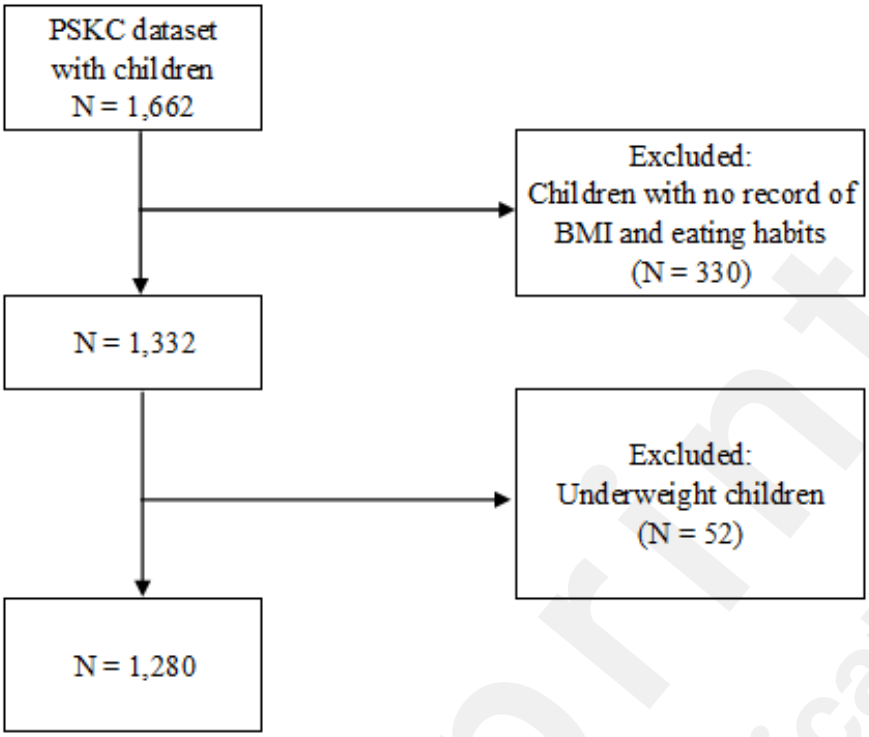


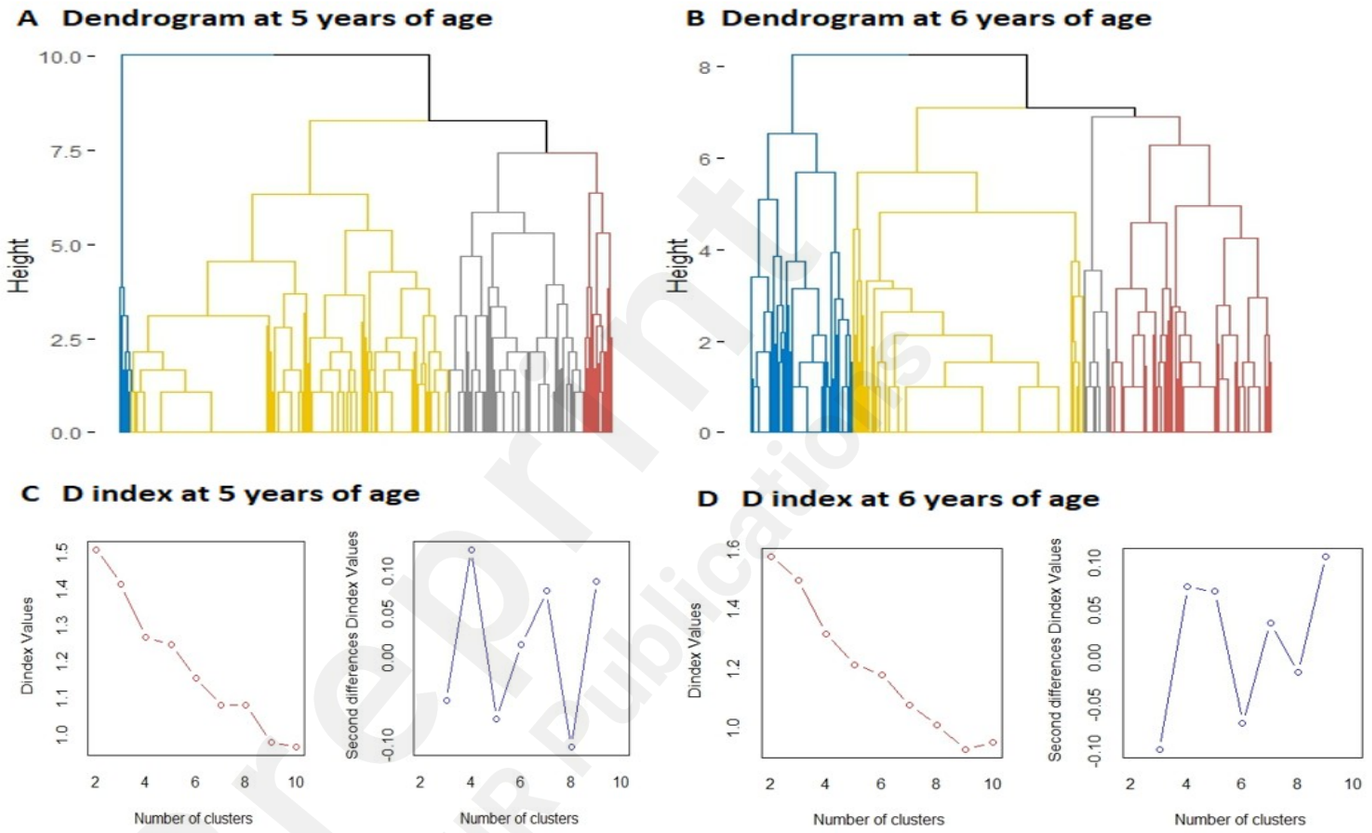
Figure 2 (A) The cluster changes from five to six years of age in the fast eater cluster; (B) The cluster changes from five to six years of age in the slow eater cluster; (C) The cluster changes from five to six years of age in the poor eater cluster; (D) The cluster changes from five to six years of age in the healthy eater cluster. The bar graph represents the number of subjects in the clusters at 5 years old who moved to another cluster at 6 years old.

Appendix 1. Flow chart of the process of selecting the participants



BMI = body mass index; PSKC = Panel Study on Korean Children

Appendix 2. Evidence of clustering decision



Appendix 2 (A) Result of the dendrogram at age 5; (B) Result of the dendrogram at age 6; (C) Results of choosing the number of clusters at age 5; (D) Results of selecting the number of clusters at age 6. (A) and (B) visually show the hierarchical method as one of the methods for selecting the number of clusters. (C) and (D) are the results of using the NbClust package of the R program and are the process for selecting the number of clusters through the D index and elbow method.

Appendix 3. Characteristics of samples at five and six years old (N = 1,280)

Characteristics	Mean	SD	Range
At five years old			
Age (months)	62.61	1.30	60–66
Birth weight (kg)	3.268	0.41	2–4.9
Weight at 5 years old (kg)	19.48	2.64	13.5–34.5
Height at 5 years old (cm)	110	4.31	97–128
BMI at 5 years old (kg/m^2)	16.07	1.57	13.72–24.35
Eating speed	2.80	0.78	1–5
Regularity of meal time	3.88	0.75	1–5
Consistency of food amount	3.71	0.75	1–5
Balanced eating	3.28	0.94	1–5
Physical activity (hours/day)	1.14	0.81	0–5
Sleep duration (hours/day)	9.87	0.73	7–13
Family income (10,000 won)	428.3	207.42	0–3000
At six years old			
Age (months)	75.10	1.39	72–79
Weight at 6 years old (kg)	22.41	3.62	15.4–38.8
Height at 6 years old (cm)	110	4.68	97–128
BMI at 6 years old (kg/m^2)	16.27	2.01	12–30.85
Eating speed	2.98	0.85	1–5
Regularity of meal time	4.03	0.65	1–5
Consistency of food amount	3.90	0.68	1–5
Balanced eating	3.43	1	1–5
Physical activity (hours/day)	1.08	0.71	0–5
Sleep duration (hours/day)	9.76	0.68	7–13
Family income (10,000 won)	427.51	205.19	0–3000

BMI = body mass index