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Research Article

Title: Clustering patterns of obesity-related multiple lifestyle behaviors and their associations to overweight and family environments in Japanese preschool children

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Keywords: Cluster analysis, Family environment, Lifestyle behaviors, Overweight, Preschool children

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Original Article

Abstract

Objectives: 1) To identify obesity-related lifestyle patterns of diet, physical activity, sedentary and sleep behaviors in preschool children, 2) to examine the association between identified behavior clusters and overweight/obesity, and 3) to investigate differences in children's family environments according to clusters.

Design setting and participants: A cross-sectional study on 2114 preschool children aged 3-6 years who attended all childcare facilities (24 nursery schools and 10 kindergartens) in Turuoka city, Japan in April 2003 was conducted.

Main outcome measures: Parents completed a questionnaire on children's lifestyle behaviors (dinner timing, outside playtime, screen time, and night-time sleep duration), family environments (family members, maternal employment, mealtime regularity, and parents' habitual exercise and screen time), and measurements of weight and height. Cluster analysis was performed using children's four lifestyle behaviors based on those non-missing values (n=1545). Chi-square test assessed cluster differences in overweight/obesity and family environments.

Results: Six clusters were identified. Children's overweight varied across clusters (χ^2 = 16.0, p = 0.007). The cluster with the most screen time, shorter night-time sleep duration, and average dinner timing and outside playtime had the highest overweight/obesity prevalence (15.1%), while the cluster with the least screen time, the longest sleep duration, the earliest dinner timing, and average outside playtime had the lowest prevalence (4.0%). Family environments regarding mealtime regularity and participants' screen time also varied across clusters. The cluster having the highest overweight/obesity prevalence had the highest proportion of irregular mealtimes and the most screen time for parents across all clusters.

Conclusions: This study suggests that public health approaches to shape healthy lifestyle patterns in children should focus on decreasing screen-viewing time and increasing night-time sleep duration. To shape those behaviors, regular mealtimes and decreasing parents' screen time within family environments need to be targeted among family members.

Keywords: Cluster analysis, Family environment, Lifestyle behaviors, Overweight, Preschool children

Strengths and limitations of this study: Study population included preschool children who attended all childcare facilities in a city, Japan. Preschool children's comprehensive overweight-related behavior patterns were identified. Children's family environments with risk pattern of overweight were also revealed. However, the study measurements were based on the parent's reports and could not include socioeconomic status parameters.

Introduction

Multiple daily lifestyle behaviors including diet, physical activity, sedentary and sleep habits affect body weight status [1-10]. Increased body weight influences several chronic diseases such as coronary heart disease, diabetes, and metabolic syndrome [11, 12]. High energy intake, late eating at night, and excessive television (TV) viewing are associated with increased risk of overweight [1-3, 6, 7], while a high level of physical activity and long sleep duration have been shown to be protective measures against overweight [3-5, 8-10]. These lifestyle behaviors are shaped from early childhood, and adopted lifestyle behaviors carry over into adulthood [13, 14]. Hence, the development of healthy lifestyle behaviors starting from early childhood should be encouraged to achieve or maintain a healthy weight status.

Various weight-related behaviors are related to each other, and lifestyle patterns clustered around habitual behaviors, rather than individual behaviors, are considered to be related to weight status. Several studies have examined clustering patterns of multiple lifestyle behaviors in children and adolescents [15-20]. Most of the studies have focused on diet, physical activity, and/or sedentary behaviors as weight-related behaviors. However, sleep behavior is one of the habits related to risk of overweight in children [5, 10]. Except for studies in European and Australian school-age children [16, 17], no other studies were identified that included sleep habits. To promote healthy lifestyle behaviors during childhood, it is necessary to identify comprehensive lifestyle patterns, including sleeping habits as well as diet, physical activity, and sedentary behaviors.

Children's lifestyle behaviors are affected by family environments, especially among young children. Some studies considering family environments have examined the influence of family members who live with children on those children's behaviors [21-23]. These studies found that children with siblings were more physically active than an only child [23], children with one parent or a working mother spent more time watching TV [22, 23] and those with a working mother also had increased high-energy drink consumption and short sleep duration [21, 22]. Other studies have examined the influence of parents' habitual behaviors on children's behaviors [24-26]. There is evidence that children with more active parents were more physically active [24], and children with parents watching excessive TV also spent more time watching TV [25, 26]. These studies examined how the behaviors of family members living with children influenced the children's individual behavior. However, those family environments may influence children's lifestyle behavior patterns. Thus, it is important to assess associations of children's lifestyle patterns with both aspects of family environments.

The purposes of this study were 1) to identify lifestyle patterns of diet, physical activity, sedentary and sleep behaviors in preschool children, 2) to examine the association between identified behavior clusters and overweight/obesity, and 3) to investigate differences in children's family environments according to clusters.

Methods

Study design and population

This cross-sectional study was conducted in childcare facilities such as nursery schools and kindergartens in April 2003. Most preschool children aged 3 and older attend such facilities in Japan. The study population included children aged 3-6 years who attended all childcare facilities (24 nursery schools and 10 kindergartens) in Turuoka city, located in northeast Japan and their principal caregivers.

A self-administered questionnaire was delivered to the each child's principal caregiver and returned to their child's facility after completion of the questionnaire at home. Only questionnaires in which parents provided consent for study participation and were anonymously returned were included. The study was approved by the Ethics Review Committee of the University of Tokyo.

Measures

Children's lifestyle behaviors

Dinner timing was used as an indicator of dietary behaviors since a significant association between late eating at night and higher body mass index (BMI) has been observed in adults [6]. Dinner timing was recorded as the usual time of eating dinner. Outside playtime and screen time were included as indicators of being physically active or inactive. Outside playtime was recorded as hours and minutes usually spent playing outside. Screen time was recorded as hours and minutes usually spent watching TV and videos and playing electronic games. Night-time sleep duration as an indicator of sleep habit was assessed by recording usual bedtime and wake time. Night-time sleep duration was calculated as the time elapsed hours between bedtime and wake time. These behaviors for a typical weekday and weekend day were assessed separately and calculated as the mean time per day per week.

Family environments

Family members living with children. Parental status was separated into two parents or one parent. Presence of siblings and grandparents were categorized according to whether children lived with at least one sibling or grandparent. Maternal employment status was categorized as non-employed or employed (full-time, part-time, and self-employed).

Habitual family and parents' behaviors. Meal regularity was divided according to whether a family has meals at regular times or irregular times. Parents' habitual exercise was assessed by asking the respective parents to report the frequency (days/week) and duration (minutes/day) of sports or exercise. Their responses were categorized as meeting the physical activity recommendation (150 minutes/week) [27]. Parents' screen time was assessed by asking the respective parents to record the hours and minutes usually spent watching TV and videos and playing electronic games. Screen time was calculated as the mean time per day per week and categorized among the respective parents as < 2, 2-3, or ≥ 4 hours/day.

Children's anthropometric measurements

Children's body weight (kg) and height (cm) were measured with standard methods (in light clothing without shoes) at each facility before distributing the questionnaire. The measurements were recorded in health handbooks and given to principal caregivers. The principal caregivers filled out the questionnaire by referring to the handbook. BMI was calculated as body weight divided by height squared (kg/m^2). Children were classified as non-overweight or overweight (including obese) according to age- and sex-specific BMI cut-points of the International Obesity Task Force [28].

Participant characteristics

Participant characteristics included children's sex and age and parents' age, weight, and height. Parents' self-reported weight and height were used to calculate their BMI, and parents' overweight (including obese) was defined as BMI ≥ 25 kg/m^2 [29].

Statistical analysis

All statistical analyses were conducted using SAS version 9.3 (SAS Institute, Cary, NC). Cluster analysis (SAS FASTCLUS) was performed to identify subgroups with similar obesity-related lifestyle behaviors according to dinner timing, outside playtime, screen time, and night-time sleep duration. Variables used to assess those four behaviors were standardized (z-scores) before clustering to avoid the influence of variables with substantially different ranges. Cluster analysis included children who had no missing values for the behaviors and with reference to a review [30] was conducted by partitioning data into different numbers of clusters (3 to 7) by Euclidean distances between observations. Cluster solutions are sensitive to the initial cluster centers. Therefore, in order to find optimal specifications for initial cluster centers, 1000 iterations of each cluster procedure using randomly generated initial group centers were conducted. The solution with the largest overall r^2 value which represents relative heterogeneity between clusters compared to heterogeneity within clusters was identified. To examine the stability of the cluster solutions, the total sample was randomly divided into two subsamples in which the clustering procedure was repeated. Cohen's kappa coefficient of the cluster solutions of both subsamples with that of the total sample was calculated (κ = 0.92 and 0.93 for this final cluster solution). The final cluster solution was determined according to large values of the pseudo-*F* index and high interpretability and stability of cluster patterns, with reference to other studies and methodological text [15, 16, 18-20, 30, 31].

The mean values of the four lifestyle behaviors were compared across clusters using analysis of variance (ANOVA). The comparisons between clusters on participant characteristics, children's weight status, and family environments variables were performed by using chi-square tests for frequency measures and ANOVA for continuous variables. The association with children's weight status was assessed by using a multiple logistic regression model adjusted for children's sex and age in addition to the chi-square test. Two-sided p-values < 0.05 were considered as statistically significant.

Results

Study participants

At the survey, 2114 children attended all childcare facilities in the city, and a completed questionnaire was returned for 1867 (88.3%) children. Of these, 322 children were excluded due to missing analytic behavior values. The final sample included 1545 (73.1%) children (825 boys and 720 girls) and the mean age was 4.2 (s.d. 0.9) years.

Comparing included and excluded children's characteristics, there were no statistically significant differences by children's sex (53.4% and 51.5% boys, p = 0.446), age (mean 4.2 and 4.2 years, p = 0.841), overweight (8.6% and 10.6%, p = 0.213), or mothers' age (mean 33.5 and 33.3 years, p = 0.446) and BMI (mean 21.1 and 21.2 kg/m^2, p = 0.622); whereas, fathers' age (mean 36.1 and 35.4 years, p = 0.031) and BMI (mean 23.3 and 23.0 kg/m^2, p = 0.036) were different.

Cluster patterns of lifestyle behaviors

Six distinct clusters were identified. Characteristics of each cluster indicated by z-scores of lifestyle behaviors are shown in Figure 1 and the raw mean values are shown in Table 1. Cluster 1 (C1) was characterized by the earliest dinner timing, the least screen time, and the longest night-time sleep duration. Cluster 2 (C2) had as much sleep duration as in C1, but the dinner timing was relatively late when compared to other clusters. Cluster 3 (C3) was characterized by the latest dinner timing and the shortest sleep duration. Cluster 4 (C4) had the least amount of outside playtime, whereas cluster 5 (C5) had the most outside playtime. Cluster 6 (C6) was characterized by having the most screen time and shorter sleep duration.

The characteristics of participants by cluster pattern are shown in Table 2. There were significant differences in children's sex and age. C1 and C2 had higher proportions of girls, whereas C4 and C5 consisted of more boys. Children's age distribution was significantly different across clusters, and mean age was highest in C5. In addition, mothers' age was significantly different between clusters; whereas, fathers' age and overweight in both parents were not significantly different across clusters.

Differences in children's weight status and family environments by cluster pattern

The prevalence of overweight in children was significantly different across clusters and was the lowest in C1 (4.0%) and the highest in C6 (15.1%). This significant difference persisted after adjustment for children's sex and age (Table 3).

For family members living with children, presence of grandparents and maternal employment status were significantly different across clusters. Living with one or more grandparents was a higher proportion in C1 (characterized by the earliest dinner timing, the least screen time, and the longest sleep duration), C4 (characterized by the least outside playtime), and C5 (characterized by the most outside playtime) and a lower proportion in C3 (characterized by the latest dinner timing and the shortest sleep duration) and C2 (characterized by later dinner timing and longer sleep duration) across clusters. The proportion of employed mothers was lower in C1 and C2 and higher in C3 and C4. Neither parental status nor presence of siblings was significantly different across clusters.

For habitual family and parent behaviors, meal regularity and screen time in both parents were significantly different across clusters, although no differences were found for habitual exercise in either parent. The proportion of irregular meals was the lowest in C1 and the highest in C6 (characterized by the most screen time and shorter sleep duration). Marked differences were seen in parents' screen time. The proportion of excessive time spent in screen-viewing (≥ 4 hours/day) was highest in C6 compared to all other clusters for both parents.

Discussion

This study examined preschool children's lifestyle clustering patterns (including dinner timing, outside playtime, screen time, and night-time sleep duration) and their associations with children's overweight and family environments. Cluster analysis identified six clusters, and the prevalence of being overweight varied across clusters, ranging from 4.0% to 15.1%. Family environments including irregular mealtimes and parents' excessive screen time differed among lifestyle clusters.

The lifestyle pattern with the highest risk of being overweight (C6) had the most screen time, shorter sleep duration, and average dinner timing and outside playtime compared to the other clusters. Those with the lowest risk of being overweight (C1) had the least screen time, the longest sleep duration, the earliest dinner timing, and average outside playtime. Focusing on screen time and night-time sleep duration, in which notable differences were observed between the clusters, the patterns with either less screen time or longer sleep duration (C2: average screen time and long sleep duration, C3: less screen time and short sleep duration) and those with both (C1) showed lower risk of overweight than the cluster with neither behaviors (C6), regardless of dinner timing and outside playtime. These results are supported by other studies demonstrating that more screen time and short sleep duration were independent risk behaviors for childhood overweight [1, 3, 5, 7, 9, 10]. In addition, a negative association between screen-viewing and sleep duration has been found [3]. Increased screen-viewing time may lead to further decrease in sleep duration. This suggests, therefore, that low screen time and increased sleep duration could be important behaviors for achieving or maintaining a healthy weight status in children.

The lifestyle pattern with the highest risk of overweight was associated with a family environment having more screen time for both parents, not just children. Those findings are consistent in showing that a high frequency of parents who spent more screen time was associated with children's increased screen time [25, 26]. Stamatakis *et al*. [32] has reported that higher screen time in adults is associated with increased mortality and cardiovascular disease risk regardless of physical activity participation. This demonstrates that shorter screen time is a favorable behavior in parents as well as in children.

Children with the lifestyle pattern having the highest risk of overweight were also in family environments having a substantially higher proportion of irregular mealtimes as a family, although dinner timing was average. In contrast, the lifestyle pattern having the lowest risk of overweight was in family environments with the lowest proportion of irregular mealtime and the earliest dinner timing across clusters. This suggests that mealtime regularity may be more important than dinner timing for children's overweight. Although no studies were identified that examined the association between irregular mealtimes and other lifestyle behaviors, having irregular mealtimes may provide children more opportunity for watching TV while waiting for a meal and could lead to increased screen time and decreased night-time sleep duration. Farshchi *et al.* [33, 34] and Sierra-Johnson *et al.* [35] found that regular eating had beneficial effects on dietary thermogenesis and parameters of insulin resistance and metabolic syndrome in adult populations. Irregular mealtimes in family environments also have an influence on the health of not only children but also their parents and family members. A public health approach should focus on modifying those family environments to achieve and promote healthy lifestyle patterns in children along with their parents.

When family members living with children were considered, children in the clusters with a higher proportion of employed mothers (C3, C4, C5, and C6) had lifestyle patterns with shorter sleep duration and higher prevalence of overweight than the other two clusters. These findings are consistent with studies showing that length of mothers' working hours was negatively associated with children's sleep duration [21] and that maternal employment was associated with children's overweight [36, 37]. The association between maternal employment and child overweight prevalence may be mediated through night-time child sleep duration.

Children from clusters in which a higher proportion lived with at least one grandparent (C1, C4, C5, and C6) had lifestyle patterns with early dinner timing than children in the other two clusters. Although there is no study that has examined an association between mealtimes and the presence of grandparents, it is considered that grandparents who live with children may play supportive roles in caring for children and/or in preparing meals for the children and the family. By contrast, children in the clusters with higher proportion of living with grandparents (C4, C5, and C6) had higher prevalence of overweight than those with lower proportion (C3), except the two clusters with a lower proportion of employed mothers. Our previous study found that living with grandparents was more likely to contribute to children's overweight than maternal employment [38]. Those suggest that maternal employment and presence of grandparents are environmental factors that influence children's behaviors, and lifestyle patterns combined with those behaviors influence children's weight status.

Lifestyle patterns characterized by dinner timing and outside playtime were not consistently associated with children's overweight in the current study. Although an association between late dinner timing (after 8:00 pm) and high BMI has been reported in adults [6], no studies have examined this in children. Our results could not determine whether the mealtime was early or late enough to affect children's overweight. For outside playtime, the average time was 1.2 hours/day in the shortest cluster and exceeded in all clusters the physical activity recommendation for children (60 minutes/day) [27]. Although the current study did not examine intensity of children's activity, a study that assessed preschool children's physical activity in direct observation has reported that time spent outdoors were positively associated with physical activity [39]. Thus, it is possible these children had a high level of physical activity because they spent much time outdoors.

The present study has several limitations. First, this study was a cross-sectional design and therefore a causal relationship cannot be identified. Secondly, measurements were based on the parents' reports, which lack strong validity compared to objective assessments, although all behavior time variables were separately constructed on weekdays and on weekend days in order to increase precision and accuracy. Further research is needed to explore comprehensive lifestyle patterns used in objective measurements. Third, socioeconomic status, such as parents' educational level and/or household economic level, might affect the children's overweight and behaviors, but our study could not include these kinds of parameters. Despite these limitations, the current study surveyed all children attending all childcare facilities in a city with more than 100,000 in population and having almost the same as the average household income in Japan [40]. It included 93.3% of the children living in that area and yielded a relatively high response rate (73.1%). Thus, our study covered a wide range of preschool-aged children's lifestyle behavioral characteristics.

In conclusion, this study found that children's lifestyle pattern (characterized by more screen time, short sleep duration, and average dinner timing and outside playtime) is associated with the highest risk of overweight and is shaped by family environments with irregular mealtimes and more screen time in both parents. The study findings emphasize a public health approach to shape children's healthy lifestyle patterns, especially decreasing screen-viewing time and increasing night-time sleep duration, should focus on family members living with children, as well as on children, and should focus on modifying family environments, such as having regular mealtimes as a family and decreasing parents' screen time.

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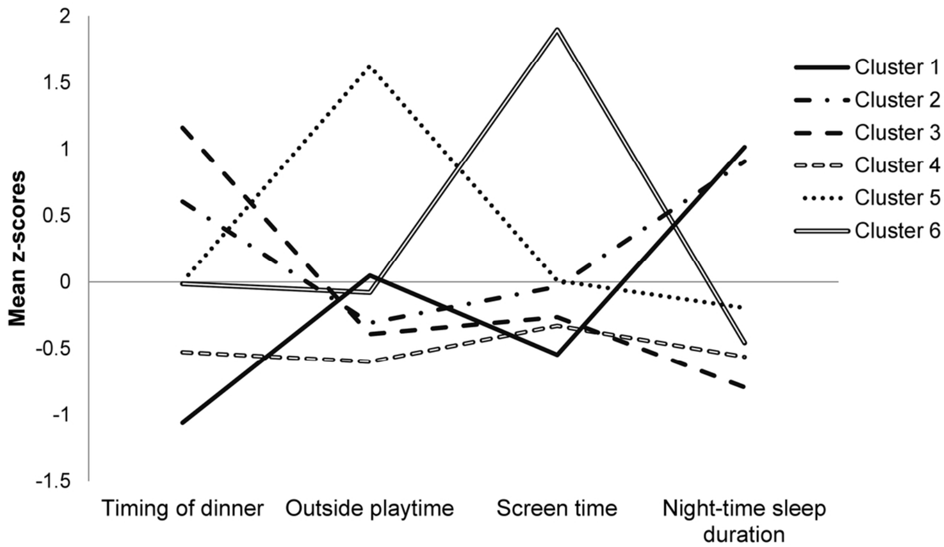

Figure 1 Final cluster centers (mean z-scores) of obesity-related lifestyle behaviors

Figure 1 Final cluster centers (mean z-scores) of obesity-related lifestyle behaviors

118x82mm (300 x 300 DPI)

Table 1 Mean values of four obesity-related lifestyle behaviors by cluster pattern

	Cluster 1 n=268		Cluster 2 n=271		Cluster 3 n=257		Cluster 4 n=336		Cluster 5 n=238		Cluster 6 n=175		
	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	*F*
Dinner timing (pm)	5:57	(0:19)	6:48	(0:19)	7:05	(0:20)	6:13	(0:17)	6:30	(0:23)	6:29	(0:26)	366.2*
Outside playtime (hours/day)	1.7	(0.6)	1.4	(0.6)	1.3	(0.6)	1.2	(0.5)	3.1	(0.6)	1.6	(0.7)	344.8*
Screen time (hours/day)	1.5	(0.8)	2.1	(0.8)	1.8	(0.8)	1.8	(0.7)	2.1	(0.8)	4.2	(0.9)	302.9*
Night-time sleep duration (hours/day)	10.4	(0.4)	10.3	(0.4)	9.2	(0.4)	9.4	(0.4)	9.6	(0.5)	9.4	(0.5)	343.7*

* $p < 0.05$ indicated significant differences between the clusters using ANOVA.

Table 2 Differences in characteristics of participants by cluster pattern

	Cluster 1 n=268		Cluster 2 n=271		Cluster 3 n=257		Cluster 4 n=336		Cluster 5 n=238		Cluster 6 n=175		χ^2 or *F*
Children													
Sex (%)													
Boys	47.0		49.0		54.5		58.6		58.4		53.1		13.8[a] *
Girls	53.0		51.0		45.5		41.4		41.6		46.9		
Age (years)	4.2	(0.9)	4.2	(0.8)	4.2	(0.8)	4.2	(0.9)	4.4	(0.9)	4.2	(0.9)	2.6[b] *
3 years (%)	24.3		23.2		24.9		27.1		17.7		24.6		25.9[a] *
4 years (%)	38.4		34.3		38.1		28.0		30.2		34.3		
5 years (%)	32.5		38.8		33.5		40.2		45.4		34.3		
6 years (%)	4.8		3.7		3.5		4.7		6.7		6.8		
Parents													
Age (years)													
Mothers	33.3	(4.1)	34.0	(4.4)	33.7	(4.8)	33.6	(4.3)	33.0	(4.1)	33.0	(4.8)	2.2[b] *
Fathers	36.0	(5.4)	36.3	(5.5)	36.2	(5.6)	36.4	(5.5)	35.5	(5.4)	36.0	(6.5)	0.7[b]
Overweight [c] (%)													
Mothers	7.5		5.8		9.8		8.2		5.6		12.3		8.3[a]
Fathers	24.1		26.4		30.5		30.3		23.0		21.2		7.9[a]

Values are provided as proportion or mean (s.d.). * p < 0.05 indicated significant differences between the clusters. [a] Chi-square value results from chi-square test. [b] *F*-value results from *ANOVA*. [c] Parents overweight (including obese) defined as body mass index ≥ 25 kg/m^2,[29]. Missing number of cases: mothers living with children (n=1532): mothers' age (65) and overweight (142); fathers living with children (n=1412): fathers' age (36) and overweight (88).

Table 3 Differences in children's overweight and family environments by cluster pattern

		Cluster 1 n=268	Cluster 2 n=271	Cluster 3 n=257	Cluster 4 n=336	Cluster 5 n=238	Cluster 6 n=175	χ^2
Children's weight status								
Non-overweight		96.0	93.2	91.6	91.0	89.0	84.9	16.0*†
Overweight[a]		4.0	6.8	8.4	9.0	11.0	15.1	
Family environments								
Family members living with children								
Parental status								
Two parents		90.6	95.2	90.7	89.9	91.2	86.9	9.9
One parent		9.4	4.8	9.3	10.1	8.8	13.1	
Presence of siblings								
None (only child)		20.1	19.2	23.0	21.4	16.4	26.3	7.3
One or more		79.9	80.8	77.0	78.6	83.6	73.7	
Presence of grandparents								
None		39.9	51.7	54.9	42.9	41.6	44.6	18.9*
One or more		60.1	48.3	45.1	57.1	58.4	55.4	
Maternal employment status								
Non-employed		38.7	39.0	17.8	16.7	23.5	23.2	67.7*
Employed		61.3	61.0	82.2	83.3	76.5	76.8	
Habitual family and parents' behaviors								
Meal regularity								
Regular		72.1	66.4	58.3	64.9	64.2	52.3	18.8*
Irregular		27.9	33.6	41.7	35.1	35.8	47.7	
Habitual exercise (minutes/week)								
Mother	< 150	98.4	99.2	97.6	98.1	96.0	97.6	6.7
	≥ 150	1.6	0.8	2.4	1.9	4.0	2.4	
Father	< 150	92.2	90.7	89.8	90.5	91.7	91.9	1.2
	≥ 150	7.8	9.3	10.2	9.5	8.3	8.1	
Screen time (hours/day)								
Mother	< 2	54.0	48.3	53.0	52.7	40.5	20.0	125.3*
	2-3	39.2	40.6	40.2	38.2	42.8	42.6	
	≥ 4	6.8	11.1	6.8	9.1	16.7	37.4	
Father	< 2	46.8	37.4	37.9	42.5	30.3	15.4	106.2*
	2-3	44.0	55.3	53.9	49.5	59.0	51.0	
	≥ 4	9.2	7.3	8.2	8.0	10.7	35.6	

Values are provided as proportion. * $p < 0.05$ indicated significant differences using chi-square test. † $p < 0.05$ indicated significant difference using multiple logistic regression analysis adjusting for children's sex and age. [a] Children's overweight (including obese) defined as age- and sex-specific BMI cut-points of the International Obesity Task Force,[28]. Missing number of cases: children's overweight (252), parental status (3), and meal regularity (286); mothers living with children (n=1532): maternal employment status (66), habitual exercise (65), and screen time (152); fathers living with children (n=1412): habitual exercise (58) and screen time (94).

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Reported on line No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	34
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	34-54
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	58-93
Objectives	3	State specific objectives, including any prespecified hypotheses	94-97
Methods			
Study design	4	Present key elements of study design early in the paper	101
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	100-109
Participants	6	(*a*) *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	102-105 162-163
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	113-154
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	113-154
Bias	9	Describe any efforts to address potential sources of bias	191-196
Study size	10	Explain how the study size was arrived at	not applicable
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	113-154
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	156-183
		(*b*) Describe any methods used to examine subgroups and interactions	156-183
		(*c*) Explain how missing data were addressed	162-163
		(*d*) *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	not applicable
		(*e*) Describe any sensitivity analyses	not applicable
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	186-196
		(b) Give reasons for non-participation at each stage	191-196
		(c) Consider use of a flow diagram	not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	198-236
		(b) Indicate number of participants with missing data for each variable of interest	Table 2, 3
Outcome data	15*	*Cross-sectional study*—Report numbers of outcome events or summary	Table 2, 3

		measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2, 3
		(*b*) Report category boundaries when continuous variables were categorized	Table 2, 3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	239-244
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	318-331
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	245-317
Generalisability	21	Discuss the generalisability (external validity) of the study results	326-331
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	364-365

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Clustering patterns of obesity-related multiple lifestyle behaviors and their associations with overweight and family environments: A cross sectional study in Japanese preschool children

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Title: Clustering patterns of obesity-related multiple lifestyle behaviors and their associations with overweight and family environments: A cross sectional study in Japanese preschool children

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Original Article

Abstract

Objectives: The purposes of this study were 1) to identify obesity-related lifestyle behavior patterns of diet, physical activity, sedentary and sleep behaviors in preschool children, 2) to examine the association between identified behavior clusters and overweight/obesity, and 3) to investigate differences in children's family environments according to clusters.

Design setting and participants: A cross-sectional study on 2114 preschool children aged 3-6 years who attended all childcare facilities (24 nursery schools and 10 kindergartens) in Tsuruoka city, Japan in April 2003 was conducted.

Main outcome measures: Children's principal caregivers completed a questionnaire on children's lifestyle behaviors (dinner timing, outside playtime, screen time, and night-time sleep duration), family environments (family members, maternal employment, mealtime regularity, and parents' habitual exercise and screen time), and measurements of weight and height. Cluster analysis was performed using children's four lifestyle behaviors based on those non-missing values (n=1545). Chi-square test and analysis of variance estimated cluster differences in overweight/obesity and family environments.

Results: Six clusters were identified. Children's overweight/obesity varied across clusters (p = 0.007). The cluster with the most screen time, shorter night-time sleep duration, and average dinner timing and outside playtime had the highest overweight/obesity prevalence (15.1%), while the cluster with the least screen time, the longest sleep duration, the earliest dinner timing, and average outside playtime had the

lowest prevalence (4.0%). Family environments regarding mealtime regularity and both parents' screen time also significantly varied across clusters. The cluster having the highest overweight/obesity prevalence had the highest proportion of irregular mealtimes and the most screen time for both parents.

Conclusions: This study suggests that public health approaches to prevent children's overweight/obesity should focus on decreasing screen time and increasing night-time sleep duration. To shape those behaviors, regular mealtimes and decreasing parents' screen time within family environments need to be targeted among family members.

Strengths and limitations of this study:

· Preschool children's obesity-related lifestyle behavior patterns including diet, physical activity, sedentary and sleep behaviors were identified using cluster analysis.

· Family environments associated with obesity-related lifestyle behavior patterns were also revealed.

· The study population included all preschool children (3-6 years) who attended childcare facilities in a city with more than 100,000 in population.

· This study was a cross-sectional design; measurements were based on the principal caregivers' reports and did not include socioeconomic status variables.

· Studies on clarifying the association with socioeconomic status in various communities are needed.

Introduction

Multiple daily lifestyle behaviors including diet, physical activity, sedentary and sleep habits affect body weight status [1-10]. Increased body weight in childhood influences several chronic diseases such as coronary heart disease, diabetes, and metabolic syndrome in childhood [11] and adulthood [12]. High energy intake, late eating at night, and excessive television (TV) viewing are associated with increased risk of overweight [1-3, 6, 7], while a high level of physical activity and long sleep duration have been shown to be protective measures against overweight [3-5, 8-10]. These lifestyle behaviors are shaped from early childhood, and adopted lifestyle behaviors carry over into adulthood [13, 14]. Hence, the development of healthy lifestyle behaviors starting from early childhood should be encouraged to achieve or maintain a healthy body weight status.

Various weight-related behaviors are related to each other, and lifestyle behavior patterns clustered around habitual behaviors, rather than individual behaviors, are considered to be related to body weight status. It is therefore important to examine weight-related lifestyle behavior patterns combined with individual behaviors. Several studies have examined clustering patterns of multiple lifestyle behaviors in children and adolescents [15-21]. Most of the studies have focused on diet, physical activity, and/or sedentary behaviors as weight-related behaviors. However, sleep behavior is one of the habits related to risk of overweight in children [5, 10]. Except for studies in European and Australian school-age children [16-18], no other studies were identified that included sleep habits. To promote healthy lifestyle behaviors during childhood, it is necessary to identify comprehensive lifestyle behavior patterns, including sleeping habits as well as diet, physical activity, and sedentary behaviors.

Children's lifestyle behaviors are affected by family environments, especially among young children. Some studies considering family environments have examined the influence of family members who live with children on those children's behaviors [22-24]. These studies found that children with siblings were more physically active than an only child [24], children with one parent or a working mother spent more time watching TV [23, 24] and those with a working mother also had increased high-energy drink consumption and short sleep duration [22, 23]. Other studies have examined the influence of parents' habitual behaviors on children's behaviors [25-27]. There is evidence that children with more active parents were more physically active [25], and children with parents watching excessive TV also spent more time watching TV [26, 27]. These studies examined how the behaviors of family members living with children influenced the children's individual behavior. However, those family environments may influence children's lifestyle behavior patterns. Thus, it is important to assess associations of children's lifestyle behavior patterns with both aspects of family environments.

The purposes of this study were 1) to identify lifestyle behavior patterns of diet, physical activity, sedentary and sleep behaviors in preschool children, 2) to examine the association between identified behavior clusters and overweight/obesity, and 3) to investigate differences in children's family environments according to clusters.

Methods

Study design and population

This cross-sectional study was conducted in childcare facilities including nursery schools and kindergartens in April 2003. Most preschool children aged 3 and older attend such facilities in Japan. The study population included all preschool children aged 3-6 years who attended childcare facilities (24 nursery schools and 10 kindergartens) in Tsuruoka city, located in northeast Japan and their principal caregivers.

A self-administered questionnaire was delivered to each child's principal caregiver and returned to the child's facility after completion of the questionnaire at home. Only questionnaires in which principal caregivers provided consent for study participation and were anonymously returned were included. The study was approved by the Ethics Review Committee of the University of Tokyo.

Measures

Children's lifestyle behaviors

Dinner timing was used as an indicator of dietary behaviors since a significant association between late eating at night and higher body mass index (BMI) has been observed in adults [6]. Dinner timing was recorded as the usual time of eating dinner. Outside playtime and screen time were included as indicators of being physically active or inactive. Outside playtime was recorded as hours and minutes usually spent playing outside. Screen time was recorded as hours and minutes usually spent watching TV and videos and playing electronic games. Night-time sleep duration as an indicator of sleep habit was assessed by recording usual bedtime and wake time. Night-time sleep duration was calculated as the time elapsed hours between bedtime and wake time. These behaviors for a usual weekday and weekend day were assessed separately and calculated as the mean time per day by summing weekdays and weekend days and dividing by seven.

Family environments

To examine the influence of family environments living with children on children's lifestyle behavior pattern, parents were referred to those who live with children, regardless of whether they are biological parents or not. Principal caregivers were referred to parents or grandparents who live with and take care of children.

Family members living with children. Parental status was separated into two parents or one parent. Presence of siblings was categorized according to whether children lived with at least one sibling. Presence of grandparents was also categorized according to whether children lived with at least one grandparent. Maternal employment status was categorized as unemployed or employed (full-time, part-time, and self-employed).

Habitual family and parents' behaviors. Meal regularity was divided according to whether a family has meals at regular times or irregular times. Parents' habitual exercise was assessed by asking each parent to report the frequency (days/week) and duration (minutes/day) of sports or exercise. Their responses were categorized as meeting the physical activity recommendation (150 minutes/week) [28]. Parents' screen time was assessed by asking each parent to record the hours and minutes usually spent watching TV and videos and playing electronic games. Screen time was calculated as the mean time per day by summing weekdays and weekend days and dividing by seven and categorized among the respective parents as < 2, 2-3, or ≥ 4 hours/day.

Children's anthropometric measurements

Children's body weight (kg) and height (cm) were measured with standard methods (in light clothing without shoes) at each facility before distributing the questionnaire, as a part of a periodic health examination. The measurements were recorded in health handbooks and given to principal caregivers. The principal caregivers filled out the questionnaire by referring to the handbook. BMI was calculated as body weight divided by height squared (kg/m^2). Children were classified as non-overweight or overweight (including obese) according to sex- and age-specific BMI cut-points of the International Obesity Task Force [29], which is internationally accepted and has been used in previous childhood obesity research conducted in many countries such as Europe, Australia, and including Japan.

Participant characteristics

Participant characteristics included children's sex and age and parents' age, weight, and height. Parents' self-reported weight and height were used to calculate their BMI, and parents' overweight (including obese) was defined as BMI ≥ 25 kg/m^2 [30].

Statistical analysis

All statistical analyses were conducted using SAS version 9.3 (SAS Institute, Cary, NC). Cluster analysis (SAS FASTCLUS) was performed to identify subgroups with similar obesity-related lifestyle behaviors according to dinner timing, outside playtime, screen time, and night-time sleep duration. Boys and girls were combined for analyses to identify representative lifestyle behavior patterns in preschool-aged children. Variables used to assess four behaviors were standardized (z-scores) before clustering in order to avoid the influence of variables with substantially different ranges. Cluster analysis included children who had no missing values for the behaviors and was conducted by partitioning data into different numbers of clusters (3 to 7) by Euclidean distances between observations [31]. Cluster solutions are sensitive to the initial cluster centers. Therefore, in order to find optimal specifications for initial cluster centers, 1000 iterations of each cluster procedure using randomly generated initial group centers were conducted. The solution with the largest overall r^2 value which represents relative heterogeneity between clusters compared to heterogeneity within clusters was identified. To examine the stability of the cluster solutions, the total sample was randomly divided into two subsamples in which the clustering procedure was repeated. Cohen's kappa coefficient of the cluster solutions of both subsamples with that of the total sample was calculated ($\kappa = 0.92$ and 0.93 for this final cluster solution). The final cluster solution was determined according to large values of the pseudo-*F* index and high interpretability and stability of cluster patterns [15, 16, 18-21, 31, 32].

The mean values of the four lifestyle behaviors were compared across clusters using analysis of variance (ANOVA). Participant characteristics, children's weight status, and family environments variables were compared by using chi-square tests for frequency measures and ANOVA for continuous variables. Two-sided *p*-values < 0.05 were considered as statistically significant. The significance level for these analyses was adjusted using the Holm's method [33] for addressing problems of multiple testing.

Results

Study participants

The survey from 2114 children who attended childcare facilities in the city completed questionnaires was returned for 1867 (88.3%) children. Of these, 322 children were excluded due to missing analytic behavior values. The final sample included 1545 (73.1%) children (825 boys and 720 girls) and the mean age was 4.2 (s.d.

0.9) years.

Comparing included and excluded children's characteristics, there were no statistically significant differences by children's sex (53.4% and 51.5% boys, $p = 0.446$), age (mean 4.2 and 4.2 years, $p = 0.841$), overweight (8.6% and 10.6%, $p = 0.213$), or mothers' age (mean 33.5 and 33.3 years, $p = 0.446$) and BMI (mean 21.1 and 21.2 kg/m^2, $p = 0.622$); whereas, fathers' age (mean 36.1 and 35.4 years, $p = 0.031$) was older and BMI (mean 23.3 and 23.0 kg/m^2, $p = 0.036$) was larger in included children.

Cluster patterns of lifestyle behaviors

Table 1 Mean values of four obesity-related lifestyle behaviors by cluster pattern

	Cluster 1 n=268		Cluster 2 n=271		Cluster 3 n=257		Cluster 4 n=336		Cluster 5 n=238		Cluster 6 n=175		*p* value comparing 6 clusters [a]	Adjusted significance level (rank) [b]	
	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)			
Dinner timing (pm)	5:57	(0:19)	6:48	(0:19)	7:05	(0:20)	6:13	(0:17)	6:30	(0:23)	6:29	(0:26)	< 0.001	0.013 (1)	c
Outside playtime (hours/day)	1.7	(0.6)	1.4	(0.6)	1.3	(0.6)	1.2	(0.5)	3.1	(0.6)	1.6	(0.7)	< 0.001	0.017 (2)	c
Screen time (hours/day)	1.5	(0.8)	2.1	(0.8)	1.8	(0.8)	1.8	(0.7)	2.1	(0.8)	4.2	(0.9)	< 0.001	0.050 (4)	c
Nighttime sleep duration (hours/day)	10.4	(0.4)	10.3	(0.4)	9.2	(0.4)	9.4	(0.4)	9.6	(0.5)	9.4	(0.5)	< 0.001	0.025 (3)	c

[a] *p* values calculated from analysis of variance (ANOVA). [b] Adjusted significance level using the Holm's method [33] for multiple testing, the first entry being the adjusted significance level and the rank in parentheses being the rank of the associated original *p* value in ascending order from most to least significant. [c] Statistically significant ($p < 0.05$) after adjustment for multiple tests using the Holm's method.

Six distinct clusters were identified. Characteristics of each cluster indicated by z-scores of lifestyle behaviors are shown in Figure 1 and the raw mean values are shown in Table 1. Cluster 1 (C1) was characterized by the earliest dinner timing, the least screen time, and the longest night-time sleep duration. Cluster 2 (C2) had as much sleep duration as in C1, but the dinner timing was relatively late when compared to other clusters. Cluster 3 (C3) was characterized by the latest dinner timing and the shortest sleep duration. Cluster 4 (C4) had the least amount of outside playtime, whereas cluster 5 (C5) had the most outside playtime. Cluster 6 (C6) was characterized by having the most screen time and shorter sleep duration.

Table 2 Differences in characteristics of participants by cluster pattern

	Cluster 1 n=268	Cluster 2 n=271	Cluster 3 n=257	Cluster 4 n=336	Cluster 5 n=238	Cluster 6 n=175	*p* value comparing 6 clusters	Adjusted significance level (rank)[c,d]
Children								
Sex (%)								
Boys	47.0	49.0	54.5	58.6	58.4	53.1	0.017 [a]	0.007 (1)
Girls	53.0	51.0	45.5	41.4	41.6	46.9		
Age (years)	4.2 (0.9)	4.2 (0.8)	4.2 (0.8)	4.2 (0.9)	4.4 (0.9)	4.2 (0.9)	0.022 [b]	0.008 (2)
3 years (%)	24.3	23.2	24.9	27.1	17.7	24.6	0.039 [a]	0.010 (3)
4 years (%)	38.4	34.3	38.1	28.0	30.2	34.3		
5 years (%)	32.5	38.8	33.5	40.2	45.4	34.3		
6 years (%)	4.8	3.7	3.5	4.7	6.7	6.8		
Parents								
Age (years)								
Mothers	33.3 (4.1)	34.0 (4.4)	33.7 (4.8)	33.6 (4.3)	33.0 (4.1)	33.0 (4.8)	0.049 [b]	0.013 (4)
Fathers	36.0 (5.4)	36.3 (5.5)	36.2 (5.6)	36.4 (5.5)	35.5 (5.4)	36.0 (6.5)	0.592 [b]	0.050 (7)
Overweight[e] (%)								
Mothers	7.5	5.8	9.8	8.2	5.6	12.3	0.143 [a]	0.017 (5)
Fathers	24.1	26.4	30.5	30.3	23.0	21.2	0.160 [a]	0.025 (6)

Values are provided as proportion or mean (s.d.). [a] *p* values calculated from chi-square test. [b] *p* values calculated from analysis of variance (ANOVA). [c] Adjusted significance level using the Holm's method [33] for multiple testing, the first entry being the adjusted significance level and the rank in parentheses being the rank of the associated original *p* value in ascending order from most to least significant. [d] All variables were not statistically significant after adjustment for multiple testing using the Holm's method. [e] Parents' overweight (including obese) defined as body mass index ≥ 25 kg/m^2 [30]. Missing number of cases: mothers living with children (n=1532): mothers' age (65) and obesity (142); fathers living with children (n=1412): fathers' age (36) and obesity (88).

The characteristics of participants by cluster pattern are shown in Table 2. C1 and C2 had higher proportions of girls, whereas C4 and C5 consisted of more boys. Children's mean age was highest in C5. However, all these characteristics of children and parents were not significant across clusters.

Differences in children's weight status and family environments by cluster pattern

The prevalence of overweight in children was significantly different across clusters and was the lowest in C1 (4.0%) and the highest in C6 (15.1%) (Table 3).

For family members living with children, presence of grandparents and maternal employment status were significantly different across clusters. Living with one or more grandparents was a higher proportion in C1 (characterized by the earliest dinner timing, the least screen time, and the longest sleep duration), C4 (characterized by the least outside playtime), and C5 (characterized by the most outside playtime) and a lower proportion in C3 (characterized by the latest dinner timing and the shortest sleep duration) and C2 (characterized by later dinner timing and longer sleep duration) across clusters. The proportion of employed mothers was lower in C1 and C2 and higher in C3 and C4. Neither parental status nor presence of siblings was significantly different across clusters.

For habitual family and parent behaviors, meal regularity and screen time in both parents were significantly different across clusters, although no differences were found for habitual exercise in either parent. The proportion of irregular meals was the lowest in C1 and the highest in C6 (characterized by the most screen time and shorter sleep duration). Marked differences were seen in parents' screen time. The proportion of excessive time spent in screen-viewing (≥ 4 hours/day) was highest in C6 compared to all other clusters for both parents.

Table 3 Differences in children's overweight and family environments by cluster pattern

		Cluster 1 n=268	Cluster 2 n=271	Cluster 3 n=257	Cluster 4 n=336	Cluster 5 n=238	Cluster 6 n=175	*p* value comparing 6 clusters[a]	Adjusted significance level (rank)[b]
Children's weight status									
Non-overweight		96.0	93.2	91.6	91.0	89.0	84.9	0.007	0.010 (6) [d]
Overweight[c]		4.0	6.8	8.4	9.0	11.0	15.1		
Family environments									
Family members living with children									
Parental status									
Two parents		90.6	95.2	90.7	89.9	91.2	86.9	0.079	0.013 (7)
One parent		9.4	4.8	9.3	10.1	8.8	13.1		
Presence of siblings									
None (only child)		20.1	19.2	23.0	21.4	16.4	26.3	0.199	0.017 (8)
One or more		79.9	80.8	77.0	78.6	83.6	73.7		
Presence of grandparents									
None		39.9	51.7	54.9	42.9	41.6	44.6	0.002	0.007 (4) [d]
One or more		60.1	48.3	45.1	57.1	58.4	55.4		
Maternal employment status									
Unemployed		38.7	39.0	17.8	16.7	23.5	23.2	< 0.001	0.006 (3) [d]
Employed		61.3	61.0	82.2	83.3	76.5	76.8		
Habitual family and parents' behaviors									
Meal regularity									
Regular		72.1	66.4	58.3	64.9	64.2	52.3	0.002	0.008 (5) [d]
Irregular		27.9	33.6	41.7	35.1	35.8	47.7		
Habitual exercise (minutes/week)									
Mother	< 150	98.4	99.2	97.6	98.1	96.0	97.6	0.240	0.025 (9)
	≥ 150	1.6	0.8	2.4	1.9	4.0	2.4		
Father	< 150	92.2	90.7	89.8	90.5	91.7	91.9	0.943	0.050 (10)
	≥ 150	7.8	9.3	10.2	9.5	8.3	8.1		
Screen time (hours/day)									
Mother	< 2	54.0	48.3	53.0	52.7	40.5	20.0	< 0.001	0.005 (1) [d]
	2-3	39.2	40.6	40.2	38.2	42.8	42.6		
	≥ 4	6.8	11.1	6.8	9.1	16.7	37.4		
Father	< 2	46.8	37.4	37.9	42.5	30.3	15.4	< 0.001	0.006 (2) [d]
	2-3	44.0	55.3	53.9	49.5	59.0	51.0		
	≥ 4	9.2	7.3	8.2	8.0	10.7	35.6		

Values are provided as proportion. [a] *p* values calculated from chi-square test. [b] Adjusted significance level using the

Holm's method [33] for multiple testing, the first entry being the adjusted significance level and the rank in parentheses the rank of the associated original *p* value in ascending order from most to least significant. [c] Children's overweight (including obese) defined as sex- and age-specific BMI cut-points of the International Obesity Task Force [29]. [d] Statistically significant ($p < 0.05$) after adjustment for multiple testing using the Holm's method. Missing number of cases: children's overweight (252), parental status (3), and meal regularlity (286); mothers living with children (n=1532): maternal employment status (66), habitual exercise (65), and screen time (152); fathers living with children (n=1412): habitual exercise (58) and screen time (94).

Discussion

This study examined preschool children's lifestyle behavior clustering patterns (including dinner timing, outside playtime, screen time, and night-time sleep duration) and their associations with children's overweight and family environments. Cluster analysis identified six clusters, and the prevalence of being overweight varied across clusters, ranging from 4.0% to 15.1%. Family environments including irregular mealtimes and parents' excessive screen time differed among clusters.

The lifestyle behavior pattern with the highest risk of being overweight (C6) had the most screen time, shorter sleep duration, and average dinner timing and outside playtime compared with the other clusters. Those with the lowest risk of being overweight (C1) had the least screen time, the longest sleep duration, the earliest dinner timing, and average outside playtime. Focusing on screen time and night-time sleep duration, in which notable differences were observed among the clusters, the patterns with either less screen time or longer sleep duration (C2: average screen time and long sleep duration, C3: less screen time and short sleep duration) and those with both (C1) showed lower risk of overweight than the cluster with neither behaviors (C6), regardless of dinner timing and outside playtime. These results are supported by other studies demonstrating that more screen time and short sleep duration were independent risk behaviors for childhood overweight [1, 3, 5, 7, 9, 10]. In addition, a negative association between screen time and sleep duration has been found [3] and increased screen time may lead to further decrease in sleep duration. This suggests, therefore, that decreased screen time and increased sleep duration could be important behaviors for achieving or maintaining a healthy body weight status in children.

The lifestyle behavior pattern with the highest risk of overweight was associated with a family environment having more screen time for both parents, not just children. These findings are consistent in showing that a high frequency of parents who spent more screen time was associated with children's increased screen time [26, 27]. Stamatakis *et al*. [34] has reported that higher screen time in adults is associated with increased mortality and cardiovascular disease risk regardless of physical activity participation, which demonstrates that shorter screen time is a favorable behavior in parents as well as in children.

Children with the lifestyle behavior pattern having the highest risk of overweight were also in family environments having a substantially higher proportion of irregular mealtimes as a family, although dinner timing was average. In contrast, the lifestyle behavior pattern having the lowest risk of overweight was in family environments with the lowest proportion of irregular mealtime and the earliest dinner timing across clusters. These results suggest that mealtime regularity may be more important than dinner timing for children's overweight. Although no studies were identified that examined the association between irregular mealtimes and other lifestyle behaviors, having irregular mealtimes may provide children more opportunity for watching TV while waiting for a meal and could lead to increased screen time and decreased night-time sleep duration. A public health approach should focus on modifying these family environments to achieve and promote healthy lifestyle behavior patterns in children along with their parents.

For family members, children in the clusters with a higher proportion of employed mothers (C3, C4, C5, and C6) had lifestyle behavior patterns with shorter sleep duration and higher prevalence of overweight than the other two clusters. These findings are consistent with studies showing that length of mothers' working hours was negatively associated with children's sleep duration [22] and that maternal employment was associated with children's overweight [35, 36]. Our previous study found that living with grandparents was more likely to contribute to children's overweight than maternal employment [37]. In the current study, children in the clusters with a higher proportion of living with grandparents (C4, C5, and C6) had also a higher prevalence of overweight than those with a lower proportion (C3), except the two clusters with a lower proportion of employed mothers. By contrast, children from clusters in which a higher proportion lived with at least one grandparent (C1, C4, C5, and C6) had lifestyle behavior patterns with early dinner timing than the children in the other two clusters. Although there is no study that has examined an association between mealtimes and the presence of grandparents, it is considered that grandparents who live with children may play supportive roles in caring for children and/or in preparing meals for the children and the family. Thus, maternal employment and presence of grandparents are environmental factors that influence children's habitual behaviors such as sleep duration and dinner timing, and lifestyle behavior patterns combined with these behaviors influence children's body weight status.

Lifestyle behavior patterns characterized by dinner timing and outside playtime were not consistently associated with children's overweight in the current study. Dinner timing is a behavior that affects skipping breakfast [38] and skipping breakfast is associated with children's overweight [39]. Thus, dinner timing is considered as an important dietary behavior. Although an association between late dinner timing (after

8:00 pm) and high BMI has been reported in adults [6], no studies have examined this in children. Our results could not determine whether the mealtime was early or late enough to affect children's overweight. For outside playtime, the average time was 1.2 hours/day in the shortest cluster and exceeded in all clusters the physical activity recommendation for children (60 minutes/day) [28]. Although the current study did not examine intensity of children's activity, a study that assessed preschool children's physical activity in direct observation has reported that time spent outdoors were positively associated with physical activity [40]. Thus, it is possible these children had a high level of physical activity because they spent much time outdoors.

The present study has several limitations. First, this study was a cross-sectional design and therefore a causal relationship cannot be identified. Secondly, measurements were based on the principal caregivers' reports, although childen's weight and height were measured at each childcare facility. Principal caregivers who directly observe children's daily behaviors were asked to report children's behaviors. Also, all behavior time variables were separately constructed on weekdays and on weekend days in order to increase accuracy. However, proxy-reporting may have introduced recall and social desirability bias [41-43]. Further research is needed to explore comprehensive lifestyle behavior patterns used in objective measurements. Third, socioeconomic status, such as parents' educational level and/or household economic level, might affect the children's overweight and behaviors, but our study could not include these kinds of variables. Fourth, the data used in our study were collected in 2003, thus lifestyle behaviors may not necessarily reflect frequencies and proportions of recent lifestyle behaviors. However, the influences of family environments on children's lifestyle behavior patterns can be considered to be unchanged over time. Despite these limitations, the current study surveyed all children attending childcare facilities in a city with more than 100,000 in population and having almost the same as the average household income in Japan [44]. It included 93.3% of the children living in that area and yielded a relatively high response rate (73.1%). Thus, our study covered a wide range of preschool-aged children's lifestyle behavioral characteristics.

In conclusion, this study found that the children's lifestyle behavior pattern (characterized by more screen time, short sleep duration, and average dinner timing and outside playtime) is associated with the highest risk of overweight and is shaped by family environments with irregular mealtimes and more screen time in both parents. The study findings emphasize a public health approach to shape children's healthy lifestyle behavior patterns, especially decreasing screen time and increasing night-time sleep duration, should focus on family members living with children, as well as on children, and should focus on modifying family environments, such as having regular mealtimes as a family and decreasing parents' screen time.

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Author contributions: All authors contributed to the writing and revising of the manuscript. EW, JSL, KM, and KK conducted data collection. EW, JSL, and KM conceived and designed this analysis and interpreted the findings. EW and KM performed the analyses. EW drafted the manuscript. The manuscript was critically reviewed by JSL, KM, and KK.

Conflict of interest statement: The authors declare that there are no conflicts of interest.

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Data sharing statement: All available data can be obtained by contacting the corresponding author.

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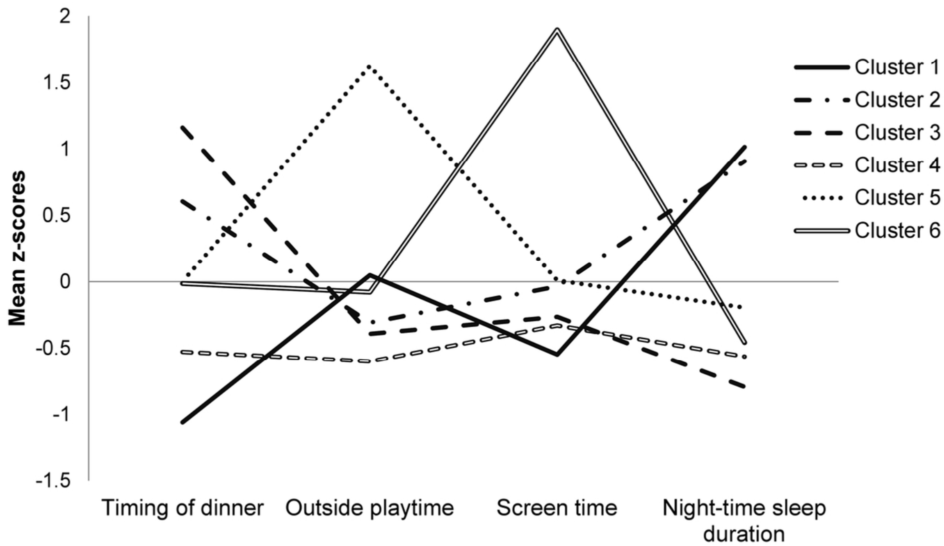

Figure 1 Final cluster centers (mean z-scores) of obesity-related lifestyle behaviors

Figure 1 Final cluster centers (mean z-scores) of obesity-related lifestyle behaviors

118x82mm (300 x 300 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Reported on line No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2-4 33
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	33-35
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	70-107
Objectives	3	State specific objectives, including any prespecified hypotheses	108-111
Methods			
Study design	4	Present key elements of study design early in the paper	115
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	115-122
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	115-119
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	128-177
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	128-177
Bias	9	Describe any efforts to address potential sources of bias	121-122
Study size	10	Explain how the study size was arrived at	Not applicable
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	129-177
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	180-205
		(*b*) Describe any methods used to examine subgroups and interactions	194-197
		(*c*) Explain how missing data were addressed	186-187
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(*e*) Describe any sensitivity analyses	Not applicable
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	209-213
		(b) Give reasons for non-participation at each stage	209-213
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	231-234 Table 2
		(b) Indicate number of participants with missing data for each variable of interest	Table 2, 3
Outcome data	15*	Report numbers of outcome events or summary measures	Table 3

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1, 2, 3
		(*b*) Report category boundaries when continuous variables were categorized	Table 2, 3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	259-264
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	335-349
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	265-349
Generalisability	21	Discuss the generalisability (external validity) of the study results	349-354
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	378-379

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Clustering patterns of obesity-related multiple lifestyle behaviors and their associations with overweight and family environments: A cross-sectional study in Japanese preschool children

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Research Article

Title: Clustering patterns of obesity-related multiple lifestyle behaviors and their associations with overweight and family environments: A cross-sectional study in Japanese preschool children

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Original Article

Abstract

Objectives: The purposes of this study were 1) to identify obesity-related lifestyle behavior patterns of diet, physical activity, sedentary and sleep behaviors in preschool children, 2) to examine the association between identified behavior clusters and overweight/obesity, and 3) to investigate differences in children's family environments according to clusters.

Design setting and participants: A cross-sectional study on 2114 preschool children aged 3-6 years who attended all childcare facilities (24 nursery schools and 10 kindergartens) in Tsuruoka city, Japan in April 2003 was conducted.

Main outcome measures: Children's principal caregivers completed a questionnaire on children's lifestyle behaviors (dinner timing, outside playtime, screen time, and night-time sleep duration), family environments (family members, maternal employment, mealtime regularity, and parents' habitual exercise and screen time), and measurements of weight and height. Cluster analysis was performed using children's four lifestyle behaviors based on those non-missing values (n=1545). Chi-square tests and analysis of variance estimated cluster differences in overweight/obesity and family environments.

Results: Six clusters were identified. Children's overweight/obesity varied across clusters (p = 0.007). The cluster with the most screen time, shorter night-time sleep duration, and average dinner timing and outside playtime had the highest overweight/obesity prevalence (15.1%), while the cluster with the least screen time, the longest sleep duration, the earliest dinner timing, and average outside playtime had the lowest prevalence (4.0%). Family environments regarding mealtime regularity and both parents' screen time also significantly varied across clusters. The cluster having the highest overweight/obesity prevalence had the highest proportion of irregular mealtimes and the most screen time for both parents.

Conclusions: This study suggests that public health approaches to prevent children's overweight/obesity should focus on decreasing screen time and increasing night-time sleep duration. To shape those behaviors, regular mealtimes and decreasing parents' screen time within family environments need to be targeted among family members.

Strengths and limitations of this study:

- Preschool children's obesity-related lifestyle behavior patterns including diet, physical activity, sedentary and sleep behaviors were identified using cluster analysis.
- The study population included all preschool children (3-6 years) who attended childcare facilities in a city with more than 100,000 in population.
- This study was a cross-sectional design; measurements were based on the principal caregivers' reports and did not include socioeconomic status variables.
- Studies on clarifying the association with socioeconomic status in various communities are needed.

Introduction

Multiple daily lifestyle behaviors including diet, physical activity, sedentary and sleep habits affect body weight status [1-10]. Increased body weight in childhood influences several chronic diseases such as coronary heart disease, diabetes, and metabolic syndrome in childhood [11] and adulthood [12]. High energy intake, late eating at night, and excessive television (TV) viewing are associated with increased risk of overweight [1-3, 6, 7], while a high level of physical activity and long sleep duration have been shown to be protective measures against overweight [3-5, 8-10]. These lifestyle behaviors are shaped from early childhood, and adopted lifestyle behaviors carry over into adulthood [13, 14]. Hence, the development of healthy lifestyle behaviors starting from early childhood should be encouraged to achieve or maintain a healthy body weight status.

Various weight-related behaviors are related to each other, and lifestyle behavior patterns clustered around habitual behaviors, rather than individual behaviors, are considered to be related to body weight status. It is therefore important to examine weight-related lifestyle behavior patterns combined with individual behaviors. Several studies have examined clustering patterns of multiple lifestyle behaviors in children and adolescents [15-21]. Most of the studies have focused on diet, physical activity, and/or sedentary behaviors as weight-related behaviors. However, sleep behavior is one of the habits related to risk of overweight in children [5, 10]. Except for studies in European and Australian school-age children [16-18], no other studies were identified that included sleep habits. To promote healthy lifestyle behaviors during childhood, it is necessary to identify comprehensive lifestyle behavior patterns, including sleeping habits as well as diet, physical activity, and sedentary behaviors.

Children's lifestyle behaviors are affected by family environments, especially among young children. Some studies considering family environments have examined the influence of family members who live with children on those children's behaviors [22-24]. These studies found that children with siblings were more physically active than an only child [24], children with one parent or a working mother spent more time watching TV [23, 24] and those with a working mother also had increased high-energy drink consumption and short sleep duration [22, 23]. Other studies have examined the influence of parents' habitual behaviors on children's behaviors [25-27]. There is evidence that children with more active parents were more physically active [25], and children with parents watching excessive TV also spent more time watching TV [26, 27]. These studies examined how the behaviors of family members living with children influenced the children's individual behavior. However, those family environments may influence children's lifestyle behavior patterns. Thus, it is important to assess associations of children's lifestyle behavior patterns with both aspects of family environments.

The purposes of this study were 1) to identify lifestyle behavior patterns of diet, physical activity, sedentary and sleep behaviors in preschool children, 2) to examine the association between identified behavior clusters and overweight/obesity, and 3) to investigate differences in children's family environments according to clusters.

Methods

Study design and population

This cross-sectional study was conducted in childcare facilities including nursery schools and kindergartens in April 2003. Most preschool children aged 3 and older attend such facilities in Japan. The study population included all preschool children aged 3-6 years who attended childcare facilities (24 nursery schools and 10 kindergartens) in Tsuruoka city, located in northeast Japan and their principal caregivers.

A self-administered questionnaire was delivered to each child's principal caregiver and returned to the child's facility after completion of the questionnaire at home. Only questionnaires in which principal caregivers provided consent for study participation and were anonymously returned were included. The study was approved by the Ethics Review Committee of the University of Tokyo.

Measures

Children's lifestyle behaviors

Dinner timing was used as an indicator of dietary behaviors since a significant association between late eating at night and higher body mass index (BMI) has been observed in adults [6]. Dinner timing was recorded as the usual time of eating dinner. Outside playtime and screen time were included as indicators of being physically active or inactive. Outside playtime was recorded as hours and minutes usually spent playing outside. Screen time was recorded as hours and minutes usually spent watching TV and videos and playing electronic games. Night-time sleep duration as an indicator of sleep habit was assessed by recording usual bedtime and wake time. Night-time sleep duration was calculated as the time elapsed hours between bedtime and wake time. These behaviors for a usual weekday and weekend day were assessed separately and calculated as the mean time per day by summing weekdays and weekend days and dividing by seven.

Family environments

To examine the influence of family environments living with children on children's lifestyle behavior pattern, parents were referred to those who live with children, regardless of whether they are biological parents or not. Principal caregivers were referred to parents or grandparents who live with and take care of children.

Family members living with children. Parental status was separated into two parents or one parent. Presence of siblings was categorized according to whether children lived with at least one sibling. Presence of grandparents was also categorized according to whether children lived with at least one grandparent. Maternal employment status was categorized as unemployed or employed (full-time, part-time, and self-employed).

Habitual family and parents' behaviors. Meal regularity was divided according to whether a family has meals at regular times or irregular times. Parents' habitual exercise was assessed by asking each parent to report the frequency (days/week) and duration (minutes/day) of sports or exercise. Their responses were categorized as meeting the physical activity recommendation (150 minutes/week) [28]. Parents' screen time was assessed by asking each parent to record the hours and minutes usually spent watching TV and videos and playing electronic games. Screen time was calculated as the mean time per day by summing weekdays and weekend days and dividing by seven and categorized among the respective parents as < 2, 2-3, or ≥ 4 hours/day.

Children's anthropometric measurements

Children's body weight (kg) and height (cm) were measured with standard methods (in light clothing without shoes) at each facility before distributing the questionnaire, as a part of a periodic health examination. The measurements were recorded in health handbooks and given to principal caregivers. The principal caregivers filled out the questionnaire by referring to the handbook. BMI was calculated as body weight divided by height squared (kg/m^2). Children were classified as non-overweight or overweight (including obese) according to sex- and age-specific BMI cut-points of the International Obesity Task Force [29], which is internationally accepted and has been used in previous childhood obesity research conducted in many countries such as Europe [1-4, 16, 20, 30, 31], Australia [15, 17], and Japan [32].

Participant characteristics

Participant characteristics included children's sex and age and parents' age, weight, and height. Parents' self-reported weight and height were used to calculate their BMI, and parents' overweight (including obese) was defined as BMI ≥ 25 kg/m^2 [33].

Statistical analysis

All statistical analyses were conducted using SAS version 9.3 (SAS Institute, Cary, NC). Cluster analysis (SAS FASTCLUS) was performed to identify subgroups with similar obesity-related lifestyle behaviors according to dinner timing, outside playtime, screen time, and night-time sleep duration. Boys and girls were combined for analyses to identify representative lifestyle behavior patterns in preschool-aged children. Variables used to assess four behaviors were standardized (z-scores) before clustering in order to avoid the influence of variables with substantially different ranges. Cluster analysis included children who had no missing values for the behaviors and was conducted by partitioning data into different numbers of clusters (3 to 7) by Euclidean distances between observations [34]. Cluster solutions are sensitive to the initial cluster centers. Therefore, in order to find optimal specifications for initial cluster centers, 1000 iterations of each cluster procedure using randomly generated initial group centers were conducted. The solution with the largest overall r^2 value which represents relative heterogeneity between clusters compared to heterogeneity within clusters was identified. To examine the stability of the cluster solutions, the total sample was randomly divided into two subsamples in which the clustering procedure was repeated. Cohen's kappa coefficient of the cluster solutions of both subsamples with that of the total sample was calculated (κ = 0.92 and 0.93 for this final cluster solution). The final cluster solution was determined according to large values of the pseudo-*F* index and high interpretability and stability of cluster patterns [15, 16, 18-21, 34, 35].

The mean values of the four lifestyle behaviors were compared across clusters using analysis of variance (ANOVA). Participant characteristics, children's weight status, and family environments variables were compared by using chi-square tests for frequency measures and ANOVA for continuous variables. Two-sided *p*-values < 0.05 were considered as statistically significant. The significance level for these analyses was adjusted using the Holm's method [36] for addressing problems of multiple testing.

Results

Study participants

Surveyed target participant was 2114 children who attended childcare facilities in the city, and 1867 (88.3%) returned a completed questionnaire. Of these, 322 children were excluded due to missing analytic behavior values. The final sample included 1545 (73.1%) children (825 boys and 720 girls) and the mean age was 4.2 (s.d. 0.9) years.

Comparing included and excluded children's characteristics, there were no statistically significant differences by children's sex (53.4% and 51.5% boys, p = 0.446), age (mean 4.2 and 4.2 years, p = 0.841), overweight (8.6% and 10.6%, p = 0.213), or mothers' age (mean 33.5 and 33.3 years, p = 0.446) and BMI (mean 21.1 and 21.2 kg/m^2, p = 0.622); whereas, fathers' age (mean 36.1 and 35.4 years, p = 0.031) was older and father's BMI (mean 23.3 and 23.0 kg/m^2, p = 0.036) was larger in included children.

Cluster patterns of lifestyle behaviors

Table 1 Mean values of four obesity-related lifestyle behaviors by cluster pattern

	Cluster 1 n=268		Cluster 2 n=271		Cluster 3 n=257		Cluster 4 n=336		Cluster 5 n=238		Cluster 6 n=175		*p* value comparing 6 clusters [a]	Adjusted significance level (rank) [b]	
	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)			
Dinner timing (pm)	5:57	(0:19)	6:48	(0:19)	7:05	(0:20)	6:13	(0:17)	6:30	(0:23)	6:29	(0:26)	< 0.001	0.013 (1)	c
Outside playtime (hours/day)	1.7	(0.6)	1.4	(0.6)	1.3	(0.6)	1.2	(0.5)	3.1	(0.6)	1.6	(0.7)	< 0.001	0.017 (2)	c
Screen time (hours/day)	1.5	(0.8)	2.1	(0.8)	1.8	(0.8)	1.8	(0.7)	2.1	(0.8)	4.2	(0.9)	< 0.001	0.050 (4)	c
Nighttime sleep duration (hours/day)	10.4	(0.4)	10.3	(0.4)	9.2	(0.4)	9.4	(0.4)	9.6	(0.5)	9.4	(0.5)	< 0.001	0.025 (3)	c

[a] *p* values calculated from analysis of variance (ANOVA). [b] Adjusted significance level using the Holm's method [33] for multiple testing, the first entry being the adjusted significance level and the rank in parentheses being the rank of the associated original *p* value in ascending order from most to least significant. [c] Statistically significant (p < 0.05) after adjustment for multiple tests using the Holm's method.

Six distinct clusters were identified. Characteristics of each cluster indicated by z-scores of lifestyle behaviors are shown in Figure 1 and the raw mean values are shown in Table 1. Cluster 1 (C1) was characterized by the earliest dinner timing, the least screen time, and the longest night-time sleep duration. Cluster 2 (C2) had as much sleep duration as in C1, but the dinner timing was relatively late when compared to other clusters. Cluster 3 (C3) was characterized by the latest dinner timing and the shortest sleep duration. Cluster 4 (C4) had the least amount of outside playtime, whereas cluster 5 (C5) had the most outside playtime. Cluster 6 (C6) was characterized by having the most screen time and shorter sleep duration.

Table 2 Differences in characteristics of participants by cluster pattern

	Cluster 1 n=268	Cluster 2 n=271	Cluster 3 n=257	Cluster 4 n=336	Cluster 5 n=238	Cluster 6 n=175	*p* value comparing 6 clusters	Adjusted significance level (rank)[c,d]
Children								
Sex (%)								
Boys	47.0	49.0	54.5	58.6	58.4	53.1	0.017 [a]	0.007 (1)
Girls	53.0	51.0	45.5	41.4	41.6	46.9		
Age (years)	4.2 (0.9)	4.2 (0.8)	4.2 (0.8)	4.2 (0.9)	4.4 (0.9)	4.2 (0.9)	0.022 [b]	0.008 (2)
3 years (%)	24.3	23.2	24.9	27.1	17.7	24.6	0.039 [a]	0.010 (3)
4 years (%)	38.4	34.3	38.1	28.0	30.2	34.3		
5 years (%)	32.5	38.8	33.5	40.2	45.4	34.3		
6 years (%)	4.8	3.7	3.5	4.7	6.7	6.8		
Parents								
Age (years)								
Mothers	33.3 (4.1)	34.0 (4.4)	33.7 (4.8)	33.6 (4.3)	33.0 (4.1)	33.0 (4.8)	0.049 [b]	0.013 (4)
Fathers	36.0 (5.4)	36.3 (5.5)	36.2 (5.6)	36.4 (5.5)	35.5 (5.4)	36.0 (6.5)	0.592 [b]	0.050 (7)
Overweight[e] (%)								
Mothers	7.5	5.8	9.8	8.2	5.6	12.3	0.143 [a]	0.017 (5)
Fathers	24.1	26.4	30.5	30.3	23.0	21.2	0.160 [a]	0.025 (6)

Values are provided as proportion or mean (s.d.). [a] *p* values calculated from chi-square test. [b] *p* values calculated from analysis of variance (ANOVA). [c] Adjusted significance level using the Holm's method [33] for multiple testing, the first entry being the adjusted significance level and the rank in parentheses being the rank of the associated original *p* value in ascending order from most to least significant. [d] All variables were not statistically significant after adjustment for multiple testing using the Holm's method. [e] Parents' overweight (including obese) defined as body mass index ≥ 25 kg/m^2 [30]. Missing number of cases: mothers living with children (n=1532): mothers' age (65) and obesity (142); fathers living with children (n=1412): fathers' age (36) and obesity (88).

The characteristics of participants by cluster pattern are shown in Table 2. C1 and C2 had higher proportions of girls, whereas C4 and C5 consisted of more boys. Children's mean age was highest in C5. However, all these characteristics of children and parents were not significantly different across clusters.

Differences in children's weight status and family environments by cluster pattern

The prevalence of overweight in children was significantly different across clusters and was the lowest in C1 (4.0%) and the highest in C6 (15.1%) (Table 3).

For family members living with children, presence of grandparents and maternal employment status were significantly different across clusters. Living with one or more grandparents was a higher proportion in C1 (characterized by the earliest dinner timing, the least screen time, and the longest sleep duration), C4 (characterized by the least outside playtime), and C5 (characterized by the most outside playtime) and a lower proportion in C3 (characterized by the latest dinner timing and the shortest sleep duration) and C2 (characterized by later dinner timing and longer sleep duration) across clusters. The proportion of employed mothers was lower in C1 and C2 and higher in C3 and C4. Neither parental status nor presence of siblings was significantly different across clusters.

For habitual family and parent behaviors, meal regularity and screen time in both parents were significantly different across clusters, although no differences were found for habitual exercise in either parent. The proportion of irregular meals was the lowest in C1 and the highest in C6 (characterized by the most screen time and shorter sleep duration). Marked differences were seen in parents' screen time. The proportion of excessive time spent in screen-viewing (≥ 4 hours/day) was highest in C6 compared to all other clusters for both parents.

Table 3 Differences in children's overweight and family environments by cluster pattern

		Cluster 1 n=268	Cluster 2 n=271	Cluster 3 n=257	Cluster 4 n=336	Cluster 5 n=238	Cluster 6 n=175	*p* value comparing 6 clusters[a]	Adjusted significance level (rank)[b]
Children's weight status									
Non-overweight		96.0	93.2	91.6	91.0	89.0	84.9	0.007	0.010 (6) [d]
Overweight[c]		4.0	6.8	8.4	9.0	11.0	15.1		
Family environments									
Family members living with children									
Parental status									
Two parents		90.6	95.2	90.7	89.9	91.2	86.9	0.079	0.013 (7)
One parent		9.4	4.8	9.3	10.1	8.8	13.1		
Presence of siblings									
None (only child)		20.1	19.2	23.0	21.4	16.4	26.3	0.199	0.017 (8)
One or more		79.9	80.8	77.0	78.6	83.6	73.7		
Presence of grandparents									
None		39.9	51.7	54.9	42.9	41.6	44.6	0.002	0.007 (4) [d]
One or more		60.1	48.3	45.1	57.1	58.4	55.4		
Maternal employment status									
Unemployed		38.7	39.0	17.8	16.7	23.5	23.2	< 0.001	0.006 (3) [d]
Employed		61.3	61.0	82.2	83.3	76.5	76.8		
Habitual family and parent behaviors									
Meal regularity									
Regular		72.1	66.4	58.3	64.9	64.2	52.3	0.002	0.008 (5) [d]
Irregular		27.9	33.6	41.7	35.1	35.8	47.7		
Habitual exercise (minutes/week)									
Mother	< 150	98.4	99.2	97.6	98.1	96.0	97.6	0.240	0.025 (9)
	≥ 150	1.6	0.8	2.4	1.9	4.0	2.4		
Father	< 150	92.2	90.7	89.8	90.5	91.7	91.9	0.943	0.050 (10)
	≥ 150	7.8	9.3	10.2	9.5	8.3	8.1		
Screen time (hours/day)									
Mother	< 2	54.0	48.3	53.0	52.7	40.5	20.0	< 0.001	0.005 (1) [d]
	2-3	39.2	40.6	40.2	38.2	42.8	42.6		
	≥ 4	6.8	11.1	6.8	9.1	16.7	37.4		
Father	< 2	46.8	37.4	37.9	42.5	30.3	15.4	< 0.001	0.006 (2) [d]
	2-3	44.0	55.3	53.9	49.5	59.0	51.0		
	≥ 4	9.2	7.3	8.2	8.0	10.7	35.6		

Values are provided as proportion. [a] *p* values calculated from chi-square test. [b] Adjusted significance level using the

Holm's method [33] for multiple testing, the first entry being the adjusted significance level and the rank in parentheses the rank of the associated original *p* value in ascending order from most to least significant. [c] Children's overweight (including obese) defined as sex- and age-specific BMI cut-points of the International Obesity Task Force [29]. [d] Statistically significant ($p < 0.05$) after adjustment for multiple testing using the Holm's method. Missing number of cases: children's overweight (252), parental status (3), and meal regularity (286); mothers living with children (n=1532): maternal employment status (66), habitual exercise (65), and screen time (152); fathers living with children (n=1412): habitual exercise (58) and screen time (94).

Discussion

This study examined preschool children's lifestyle behavior clustering patterns (including dinner timing, outside playtime, screen time, and night-time sleep duration) and their associations with children's overweight (including obese) and family environments. Cluster analysis identified six clusters, and the prevalence of being overweight varied across clusters, ranging from 4.0% to 15.1%. Family environments including irregular mealtimes and parents' excessive screen time differed among clusters.

The lifestyle behavior pattern with the highest risk of being overweight (C6) had the most screen time, shorter sleep duration, and average dinner timing and outside playtime compared with the other clusters. Those with the lowest risk of being overweight (C1) had the least screen time, the longest sleep duration, the earliest dinner timing, and average outside playtime. Focusing on screen time and night-time sleep duration, in which notable differences were observed among the clusters, the patterns with either less screen time or longer sleep duration (C2: average screen time and long sleep duration, C3: less screen time and short sleep duration) and those with both (C1) showed lower risk of overweight than the cluster with neither behaviors (C6), regardless of dinner timing and outside playtime. These results are supported by other studies demonstrating that more screen time and short sleep duration were independent risk behaviors for childhood overweight [1, 3, 5, 7, 9, 10]. In addition, a negative association between screen time and sleep duration has been found [3] and increased screen time may lead to further decrease in sleep duration. This suggests, therefore, that decreased screen time and increased sleep duration could be important behaviors for achieving or maintaining a healthy body weight status in children.

The lifestyle behavior pattern with the highest risk of overweight was associated with a family environment having more screen time for both parents, not just children. These findings are consistent in showing that a high frequency of parents who spent more screen time was associated with children's increased screen time [26, 27]. Stamatakis *et al*. [37] has reported that excessive screen time in adults is associated with increased mortality and cardiovascular disease risk regardless of physical activity participation, which demonstrates that decreased screen time is a favorable behavior in parents as well as in children.

Children with the lifestyle behavior pattern having the highest risk of overweight were also in family environments having a substantially higher proportion of irregular mealtimes as a family, although dinner timing was average. In contrast, the lifestyle behavior pattern having the lowest risk of overweight was in family environments with the lowest proportion of irregular mealtime and the earliest dinner timing across clusters. These results suggest that mealtime regularity may be more important than dinner timing for children's overweight. Although no studies were identified that examined the association between irregular mealtimes and other lifestyle behaviors, having irregular mealtimes may provide children more opportunity for watching TV while waiting for a meal and could lead to increased screen time and decreased night-time sleep duration. A public health approach should focus on modifying these family environments to achieve and promote healthy lifestyle behavior patterns in children along with their parents.

For family members, children in the clusters with a higher proportion of employed mothers (C3, C4, C5, and C6) had lifestyle behavior patterns with shorter sleep duration and higher prevalence of overweight than the other two clusters. These findings are consistent with studies showing that length of mothers' working hours was negatively associated with children's sleep duration [22] and that maternal employment was associated with children's overweight [30, 31]. Our previous study found that living with grandparents was more likely to contribute to children's overweight than maternal employment [32]. In the current study, children in the clusters with a higher proportion of living with grandparents (C4, C5, and C6) had also a higher prevalence of overweight than those with a lower proportion (C3), except the two clusters with a lower proportion of employed mothers. By contrast, children from clusters in which a higher proportion lived with at least one grandparent (C1, C4, C5, and C6) had lifestyle behavior patterns with early dinner timing than the children in the other two clusters. Although there is no study that has examined an association between mealtimes and the presence of grandparents, it is considered that grandparents who live with children may play supportive roles in caring for children and/or in preparing meals for the children and the family. Thus, maternal employment and presence of grandparents are environmental factors that influence children's habitual behaviors such as sleep duration and dinner timing, and lifestyle behavior patterns combined with these behaviors influence children's body weight status.

Among four lifestyle behaviors we examined, dinner timing and outside playtime were not consistently associated with children's overweight. Dinner timing is a behavior that affects skipping breakfast [38] and skipping breakfast is associated with children's overweight [39]. Thus, dinner timing is considered as an important dietary behavior.

Although an association between late dinner timing (after 8:00 pm) and high BMI has been reported in adults [6], no studies have examined this in children. Our results could not determine whether the mealtime was early or late enough to affect children's overweight. For outside playtime, the average time was 1.2 hours/day in the shortest cluster and exceeded in all clusters the physical activity recommendation for children (60 minutes/day) [28]. Although the current study did not examine intensity of children's activity, a study that assessed preschool children's physical activity in direct observation has reported that time spent outdoors were positively associated with physical activity [40]. Thus, it is possible these children had a sufficient active level of physical activity because they spent much time outdoors.

The present study has several limitations. First, this study was a cross-sectional design and therefore a causal relationship cannot be identified. Secondly, measurements were based on the principal caregivers' reports, although childen's weight and height were measured at each childcare facility. Principal caregivers who directly observe children's daily behaviors were asked to report children's behaviors. Also, all behavior time variables were separately constructed on weekdays and on weekend days in order to increase accuracy. However, proxy-reporting may have introduced recall and social desirability bias [41-43]. Further research is needed to explore comprehensive lifestyle behavior patterns used in objective measurements. Third, socioeconomic status, such as parents' educational level and/or household economic level, might affect the children's overweight and behaviors, but our study could not include these kinds of variables. Fourth, the data used in our study were collected in 2003, thus lifestyle behaviors may not necessarily reflect frequencies and proportions of recent lifestyle behaviors. However, the influences of lifestyle behavior patterns on body weight status and family environments on children's lifestyle behavior patterns can be considered to be unchanged over time. Despite these limitations, the current study surveyed almost the same city as the average household income in Japan [44]. The survey was conducted all children attending childcare facilities in a city with more than 100,000 in population and included 93.3% of the children living in that area and yielded a relatively high response rate (73.1%). Thus, our study covered a wide range of preschool-aged children's lifestyle behavioral characteristics.

In conclusion, this study found that the children's lifestyle behavior pattern (characterized by more screen time, short sleep duration, and average dinner timing and outside playtime) is associated with the highest risk of overweight and is shaped by family environments with irregular mealtimes and more screen time in both parents. The study findings emphasize a public health approach to shape children's healthy lifestyle behavior patterns, especially decreasing screen time and increasing night-time sleep duration, should focus on family members living with children, as well as on children, and should focus on modifying family environments, such as having regular mealtimes as a family and decreasing parents' screen time.

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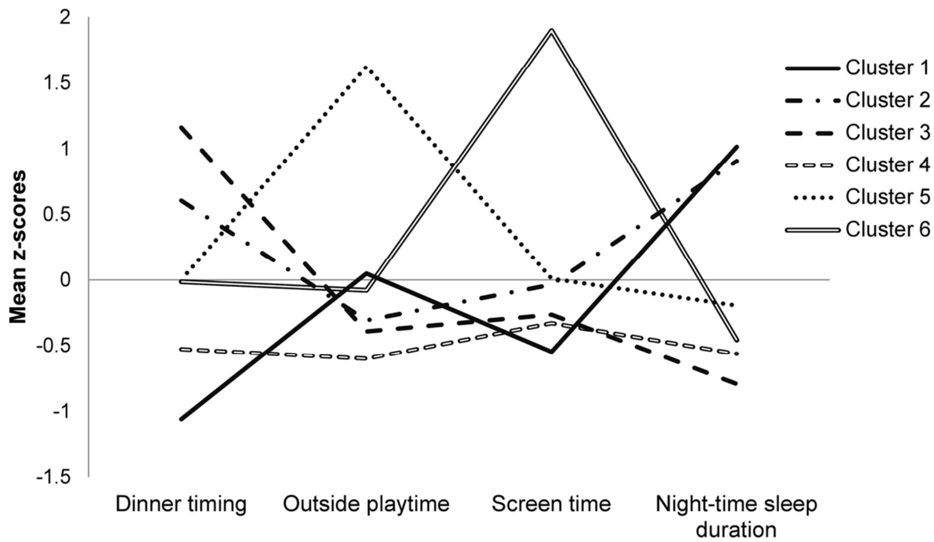

Figure 1 Final cluster centers (mean z-scores) of obesity-related lifestyle behaviors

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115x76mm (300 x 300 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Reported on line No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2-4 33
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	33-35
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	70-107
Objectives	3	State specific objectives, including any prespecified hypotheses	108-111
Methods			
Study design	4	Present key elements of study design early in the paper	115
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	115-122
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	115-119
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	128-177
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	128-177
Bias	9	Describe any efforts to address potential sources of bias	121-122
Study size	10	Explain how the study size was arrived at	Not applicable
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	129-177
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	180-205
		(*b*) Describe any methods used to examine subgroups and interactions	194-197
		(*c*) Explain how missing data were addressed	186-187
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(*e*) Describe any sensitivity analyses	Not applicable
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	209-213
		(b) Give reasons for non-participation at each stage	209-213
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	231-234 Table 2
		(b) Indicate number of participants with missing data for each variable of interest	Table 2, 3
Outcome data	15*	Report numbers of outcome events or summary measures	Table 3

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1, 2, 3
		(*b*) Report category boundaries when continuous variables were categorized	Table 2, 3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	259-264
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	335-349
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	265-349
Generalisability	21	Discuss the generalisability (external validity) of the study results	349-354
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	378-379

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.