Original Article

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Lifestyle factors related to temperature rhythms in children

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Abstract

The purpose of this study was to clarify the relationship between lifestyle and temperature rhythm in child. We conducted a cross-sectional study with 254 subjects. The study consisted of the day-by-day measurement of childrens' temperature rhythms and lifestyle factors such as their sleep-wake rhythm, meals, etc., and a self-administered questionnaire completed by the parents of the enrolled subjects. An analysis of the results of the survey found that the children went to bed at approximately 10:00 PM and woke up at approximately 7:20 AM. Approximately 50% of children had entrained body temperature rhythms, and the proportion increased for children 4 years old and older. Body temperature rhythms were related to time of going to sleep, time of waking up, and their age in months, and the body temperature rhythms showed higher entrainment for earlier time of going to sleep and time of waking up, as well as for higher age in months. The factor with the strongest relationship was time of going to sleep. The time of going to sleep had the strongest relationship with the body temperature rhythm for both the younger children and the older children. In addition, a relationship was observed for the time of waking up among the younger children.

Key words

children, biological rhythm, temperature rhythm, sleep-wake rhythm, lifestyle

Introduction

In recent years, there have been many reports that environmental changes are influencing children's' bodies and minds[1-5]. These changes were first mentioned by school staff involved in child health management, such as school nurses, in the 1960s and have gradually come to the attention of the mass media. In the 1990s, a national study was conducted, mainly by school nurses, on children's lifestyles and hypothermia, which produced many reports on the current status of this topic[6-9]. However, there are views that these reports are affected largely by the wide use of electronic thermometers and measurement errors due to measurement skills and methods; therefore, doubts have arisen as to the credibility of such studies[10, 11].

However, there have been reports that suggest that biological rhythms have become irregular because of nocturnal lifestyles, such as the use of 24-hour convenience stores. Kohyama stated that the irregularity of melatonin rhythms caused by exposure to artificial lights until late hours causes irregularities in the sleep-wake cycle, resulting in chronic jet-lag states in children[1]. Also, Miyake reported the irregularity of the sleep-wake cycle as a potential risk of suppressing body temperature increases in children during the day, which lowers children's' activity levels[2]. These children, who have been unable to be active during the day, are considered to have difficulty falling asleep at night and cannot obtain sufficient sleep for their age, as their body temperatures do not fall during sleep. Furthermore, insufficient sleep is related to not eating breakfast the next day[12], which results in lower concentration and irritability by the child,

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thereby accumulating chronic fatigue[13]. These reports suggest the possibility of undesirable lifestyles causing abnormalities in children's body temperature rhythms, which then cause vicious cycles.

Body temperature is commonly used as a convenient means of understanding a person's state of health, and it is known that children's body temperatures are higher than those of adults[14] and that the temperatures are unstable, being susceptible to external influences[15]. Also, body temperature changes according to a circadian rhythm, which has a set phase relationship with sleep whereby the body temperature starts to decrease 2–3 hours before the commencement of sleep, starts to rise again during the latter half of sleep. In children, the circadian rhythm of body temperature starts to appear from the age of 8–10 months and reaches a level similar to that of adults by late infancy[16]. Therefore, infancy is an important period in the formation of body temperature rhythm, and it is feared that an undesirable lifestyle during this period has an influence on the process of forming children's body temperature rhythms.

In addition, there have been reports[17-19] of the involvement of biological rhythm abnormalities, such as those of body temperature, as one of the causes of children not attending school or locking themselves in their rooms (*hikikomori*), which have become increasing problems in recent years. However, most of these reports deal with primary to high school students who present problems from this influence on the mind and body, and although there have been many reports conserned over the influence lifestyle has on the bodies of infants during the formation of body temperature rhythms, many of these reports are limited to reporting lifestyle circumstances, and there are few studies investigating infant lifestyle in relation to biological rhythms.

Therefore, the body temperature of children and cortisol in their saliva, as well as their lifestyles, were investigated to clarify the relation that lifestyles and the biological rhythms of developing infants[20]. And we reported the observed relationship between body temperature rhythms and cortisol rhythms with lifestyle[21].

The purpose of this report was to conduct a further analysis focusing on body temperature rhythm and to determine the lifestyle factors that are strongly related to infant body temperature rhythms, as well as the degree of relation that lifestyle factors have on body temperature rhythms with children's ages.

Study methods

1. Subjects

Subjects were preschool children aged 1–5 years who attended four nursery schools in prefecture A in Japan, which were selected by snowball sampling. Children who were ill, premature infants, or children with disabilities that were considered to have an influence on body temperature rhythms were excluded, and children for whom 3 days or more of definitive data were observed during 5 consecutive days of the investigation period were included in the analysis.

2. Study design

The study was conducted from June to October 2002. Temperature measurements were carried out and lifestyle conditions were recorded 8 times per day for 5 consecutive days using a day-by-day plot method. In addition, parents were given a self-administered survey.

1) Body temperature measurements

Body temperature was measured 8 times per day for 5 consecutive days for each child. Measurements were carried out using an Omron MC-106B digital thermometer (non-predictive type) and were taken under the armpit. Measurement times were 8 times a day: time of waking up, at the time of attending the nursery, before lunch, after lunch, after the afternoon nap, upon leaving the nursery, before sleep, and time of going to sleep. The times were determined in consideration of the children's waking hours. Measurements for time of waking up, before sleep, and time of going to sleep were taken by the child's parents at home, and measurements at the time of attending the nursery, before lunch, after lunch, after their afternoon nap, and upon leaving

the nursery were taken by more than one researcher at the nursery school; all measurements were recorded along with the time of measurement. For the measurements at nursery schools, 10 to 12 research assistants were assigned to each school, where one research assistant measured the body temperature of three to four children. Although the interrater concordance rate among research assistants or among parents was not calculated, since different people carried out the measurements at home and in the nursery, handouts were provided explaining how to take the measurements, and sufficient practice was provided before the study to minimize measurement errors caused by any differences in measurement methods. Also, one thermometer was distributed for each child, so that the same thermometer was used throughout the study period. Regarding the handling of measurement values, data for when the child was ill, as well as outliers, which were judged as clear measurement errors, were excluded.

2) Lifestyle conditions

In terms of the sleep condition, the time the children woke up and went to sleep was examined, and from the results, their lengths of nighttime sleep were calculated. And the child's state upon waking and whether the child woke up independently were recorded; and for the sleep environment, whether there were lights on during sleep and whether there was noise were recorded as well. For the environment regarding meals, the contents of breakfast and the amount eaten, whether there was sufficient time to eat breakfast, the contents of dinner, the amount eaten, the time when dinner was taken, and whether snacks were eaten after the dinner were recorded.

3) Attributes

The age of the children, gender, family structure, date of birth, condition at birth, and development until the present were investigated by means of a paper survey of the parents. Additionally, the state of health, weight, and height of the children during the study period were obtained from the nursery school's records, and Kaup's index was calculated from these. In addition, nursery caregivers were interviewed on the parents' child-rearing attitudes.

3. Methods of analysis

1) Definition of terms

Entrainment is the state whereby biological rhythms with different cycles maintain appropriate rhythms by entrainment factors, and function to maintain homeostasis of the body by influencing each other[22]. In the present study, we used this concept mainly for body temperature rhythms and have defined entrainment as the matching of an individual's body temperature rhythm and sleep-wake cycle because there is a regular rising and falling of body temperature during the day; whereas desynchronization is defined as the non-matching of an individual's sleep-wake cycle and body temperature rhythm, and little fluctuations are seen in body temperature during a given day. We categorized these states using the criteria below.

2) Categorization of body temperature rhythms

For the measured body temperature in each time period, the mean value over the five days was used, and changes that fulfilled all of the criteria listed below were regarded to be entrained, and others were categorized as desynchronized.

Criterion 1: The body temperature rises from when the child wakes to before lunch.

Criterion 2: The body temperature decreases from when the child leaves the nursery to when they go to sleep.

Criterion 3: The minimum measured value is either at the time of waking or at the time of going to sleep.

Criterion 4: There is not less than a set difference (mean for each age − 1 SD) between the lowest measured temperature to the maximum temperature.

3) Analysis methods

The distribution of the obtained data was checked for each variable, and then aggregated for each age. In addition to this, the daily fluctuation of individual children's body temperatures was calculated from the mean over 5 days, then put into a body temperature rhythm category (entrained/desynchronized), and the relationship between the body temperature rhythm and each

Table 1. Attributes of subjects

		Total (n=259)	1 Yr (n=38)	2 Yr (n=57)	3 Yr (n=66)	4 Yr (n=47)	5 Yr (n=51)
Age in months (months)		47.1±17.4	18.9±5.1	34.9±4.2	46.9±3.7	59.4±4.0	70.6±3.3
Kaup's index		15.9± 1.6	17.1±1.6	16.0±1.4	15.6±1.2	15.1±1.2	15.3±1.7
Sex Number (%)	Male	129 (49.8)	25 (65.8)	34 (59.6)	27 (40.9)	16 (34.0)	27 (52.9)
	Female	130 (50.2)	13 (34.2)	23 (40.4)	39 (59.1)	31 (66.0)	24 (47.1)

variable was checked.

The t-test was used for the comparison of body temperature, time of waking up, time of going to sleep, length of nighttime sleep, age in months, and Kaup's index with the body temperature rhythm, and the Mann-Whitney U test was used for the comparison of the breakfast intake status with body temperature rhythm. A one-way ANOVA and the Kruskal-Wallis test were used for comparisons between ages, and the Bonferroni method was used for multiple comparisons. A χ^2 test and test of population proportions were used to compare the proportions of genders, breakfast status, sleep status, and parent's attitudes toward rearing children. For items that were found to have significant differences with body temperature rhythm, a multiple logistic regression analysis was carried out with body temperature rhythm as the response variable. For analysis of data, statistical software, JMP7.0.1, SPSS17.0J, and Excel Statistics 5.0 were used.

4. Ethical considerations

To conduct this study, after obtaining approval from principals of nursery schools, the information sheet and consent form were distributed to parents, and the explanation of the study was carried out. The information sheet explained the purpose and methodology of the study, clearly stated that participation in the study was voluntary and that it was possible to refuse participation or withdraw from the study, and there would be no disadvantage in terms of the care of the child in the nursery school for refusal to participate or withdrawal in the middle of the study. In addition, it was explained that personal information would be handled and privacy would be protected, and the results of the study would not be used for any purpose other than for the study itself. Furthermore, the recorded forms were retrieved directly from parents so that they were not seen by anyone else. The study was carried out for subjects who consented after receiving an explanation of the above steps.

Results

1. Subject's attributes (Table 1)

The subjects included 259 children comprising 38 (14.7%) in one-year-olds, 57 (22.0%) in two-year-olds, 66 (25.5%) in three-year-olds, 47 (18.1%) in four-year-olds, and 51 (19.7%) in five-year-olds. The mean±SD of age was 47±17 months (range: 12–77 months), and in terms of gender, there were 129 (49.8%) male children and 130 (50.2%) female children. In regards to the family structure, 187 (72.2%) children lived with a nuclear family, 72 (27.8%) children lived with an extended family, and 88 (33.8%) children had no siblings. Kaup's index, which is an index for children's body figures, was 17.1 for one-year-olds, 16.0 for two-year-olds, 15.6 for three-year-olds, 15.1 for four-year-olds, and 15.3 for five-year-olds, with one-year-olds having the highest values.

2. Lifestyle conditions

1) Sleep conditions (Table 2)

The overall mean ± SD for the time of waking up was 7:19 ± 34 minutes, the overall mean ± SD for the time of going to sleep was 22:01 ± 44 minutes, and the overall mean ± SD for the length of nighttime sleep was 9.3 ± 0.7 hours.

In terms of the time of waking up, there was a significant difference observed between one-year-olds and two-year-olds, with the one-year-olds waking up earlier. In terms of the time of going to sleep, significant differences were observed between one-year-olds and two-year-olds and between one-year-olds and three-year-olds, with the one-year-

Table 2. Sleep conditions

	Age	N		Comparison between ages
A. Time of Waking up	1 Yr	38	7:08 ± 37	p<.05
	2 Yr	57	7:28 ± 33	
	3 Yr	66	7:22 ± 34	
	4 Yr	47	7:12 ± 28	
	5 Yr	51	7:18 ± 37	
	Total	259	7:19 ± 34	
B. Time of going to sleep	1 Yr	38	21:43 ± 41	p<.01
	2 Yr	57	22:15 ± 44	
	3 Yr	66	22:07 ± 41	
	4 Yr	47	21:57 ± 49	
	5 Yr	51	21:54 ± 42	
	Total	259	22:01 ± 44	
C. Length of nighttime sleep	1 Yr	38	9.40 ± 0.65	n.s.
	2 Yr	57	9.18 ± 0.72	
	3 Yr	66	9.27 ± 0.68	
	4 Yr	47	9.28 ± 0.87	
	5 Yr	51	9.47 ± 0.75	
	Total	259	9.32 ± 0.73	
D. No. of days child woke up wide awake	1 Yr	38	3.95 ± 1.37	n.s.
	2 Yr	57	3.47 ± 1.55	
	3 Yr	66	3.82 ± 1.30	
	4 Yr	47	3.66 ± 1.58	
	5 Yr	51	4.00 ± 1.34	
	Total	259	3.77 ± 1.43	
E. No. of days the child woke autonomy	1 Yr	38	3.18 ± 1.43	p<.05
	2 Yr	57	2.75 ± 1.85	
	3 Yr	66	3.18 ± 1.57	
	4 Yr	47	2.15 ± 1.85	
	5 Yr	51	2.69 ± 1.70	
	Total	259	2.80 ± 1.72	
F: Sleeping environment (Whether or not lights were on during sleep: Proportion who answered "Yes")	1 Yr	38	26 (68.4)	n.s.
	2 Yr	57	35 (61.4)	
	3 Yr	66	43 (65.2)	
	4 Yr	47	33 (70.2)	
	5 Yr	51	37 (72.5)	
	Total	259	174 (67.2)	

For A–C, mean ± SD over 5 days, and used a one way ANOVA for comparisons between ages, and Bonferroni method for multiple comparisons
For D and E, mean ± SD for number of relevant days out of 5 days, and used the Kruskal Wallis test for comparisons between ages
For F, the number of children without lights on during sleep (%), and used χ^2 test for comparison between ages
Asterisks (*) indicate $p<0.05$

olds going to sleep the earliest. No significant differences in length of nighttime sleep were observed between the ages.

For the state of waking, the overall mean of the days when the child woke up wide-awake out of the 5 days was 3.8 ± 1.4 days, and no differences by age were observed. The overall mean of autonomy waking, where a child woke up themselves without being woken up was 2.8 ± 1.7 days, and a significant difference was observed between three- and four-year-olds. For the sleep environment, approximately 70% of children used lights, such as miniature bulbs and sidelights during sleep, and there were no significant differences observed by age.

2) Living conditions (Table 3)

The table shows the breakfast intake conditions that were found related to the body temperature. For the breakfast intake conditions, the amount ingested and the contents of breakfast were given

Table 3. Living conditions

	Age	N		Comparison between ages
A. Breakfast scores	1 Yr	38	2.43 ± 1.98	
	2 Yr	57	1.97 ± 1.81	* * *
	3 Yr	66	3.17 ± 1.36	
	4 Yr	47	3.28 ± 1.38	
	5 Yr	51	3.50 ± 1.20	p<.001
	Total	259	2.88 ± 1.62	
B. Regularity of breakfast time	1 Yr	38	9 (23.7)	
(Those who have irregular breakfast times)	2 Yr	57	22 (38.6)	
	3 Yr	66	20 (30.3)	
	4 Yr	47	20 (42.6)	n.s.
	5 Yr	51	18 (35.8)	
	Total	259	89 (34.4)	
C. Sufficiency of time for breakfast	1 Yr	11	4 (36.4)	
(Those who have insufficient time)	2 Yr	30	13 (43.3)	
	3 Yr	61	26 (42.6)	
	4 Yr	45	22 (48.9)	n.s.
	5 Yr	49	13 (26.5)	
	Total	196	78 (39.8)	
D. Parents' child-rearing attitude	1 Yr	38	26 (68.4)	
(Those with a good child-rearing attitude)	2 Yr	57	35 (61.4)	
	3 Yr	66	25 (37.9)	
	4 Yr	47	29 (61.7)	p<.001
	5 Yr	51	20 (39.2)	
	Total	259	135 (52.1)	

For breakfast scores in A, mean ± SD over 5 days, and one-way ANOVA was used for comparison between ages, and the Bonferroni method was used for multiple comparisons
For regularity of breakfast times in B, the number of those deemed irregular (%), and χ^2 test was used for comparison between ages
For sufficiency of time for breakfast in C, the number of those deemed to have insufficient time (%)
For parents' child-rearing attitudes in D, the number of those deemed to be "Good" (%)
Asterisks (*) indicate p<.05

a score out of 5, and the mean over 5 days was calculated. The mean was 2.88 ± 1.62 points, and significant differences were observed between two-year-olds compared with three-, four-, and five-year-olds, with the two-year-olds having the lowest score. Approximately 30% had irregular breakfast times, and approximately 40% of children had insufficient time for breakfast, however, no differences were seen between ages. For the assessment of parents' child rearing attitudes by the nursery teacher, approximately half were evaluated as "good," and the proportion of these varied with the age of the children.

3. Body temperature (Table 4)

The mean of the body temperature of each time period are presented for each age. The overall means ± SD were at the time of waking up: 35.97 ± 0.35 ℃, at the time of attending the nursery: 36.31 ± 0.33 ℃, before lunch: 36.39 ± 0.29 ℃, after lunch: 36.36 ± 0.28℃, after the nap: 36.18 ± 0.29℃, upon leaving the nursery: 36.38 ± 0.31 ℃, before sleep: 36.32 ± 0.33 ℃, and at the time of going to sleep: 36.08 ± 0.34℃.

All of the items, other than after lunch, were observed to differ with age. The body temperature was significantly higher for one-year-olds than for five-year-olds at waking and when they attended nurseries, and the body temperature was significantly higher in four-year-olds compared with five-year-olds before lunch. Furthermore, after the nap, a decrease in body temperature was observed in one- to four-year-olds who had naps in the afternoon, and the decrease in body temperature was more pronounced in two-year-olds compared with one-, four-, and five-year-olds, and also in three-year-olds compared to five-year-olds. No differences with age were seen upon leaving the nursery, before sleep, and at the time of going to

Table 4. Body temperature of each time period

	Age	N	Body temperature (℃ ; mean ± SD)	Comparison between ages
1) Time of waking up	1 Yr	38	36.01 ± 0.39	p<.05
	2 Yr	57	35.96 ± 0.37	
	3 Yr	66	36.01 ± 0.37 *	
	4 Yr	47	35.95 ± 0.27	
	5 Yr	51	35.88 ± 0.30	
	Total	259	35.97 ± 0.35	
2) At the time of attending the nursery	1 Yr	38	36.45 ± 0.37	p<.05
	2 Yr	57	36.33 ± 0.34	
	3 Yr	66	36.31 ± 0.32 *	
	4 Yr	47	36.27 ± 0.31	
	5 Yr	51	36.23 ± 0.27	
	Total	259	36.31 ± 0.33	
3) Before lunch	1 Yr	38	36.44 ± 0.33	p<.05
	2 Yr	57	36.36 ± 0.27	
	3 Yr	66	36.39 ± 0.26	
	4 Yr	47	36.48 ± 0.27 *	
	5 Yr	51	36.32 ± 0.29	
	Total	259	36.39 ± 0.29	
4) After lunch	1 Yr	38	36.36 ± 0.27	n.s.
	2 Yr	57	36.33 ± 0.25	
	3 Yr	66	36.37 ± 0.31	
	4 Yr	47	36.43 ± 0.26	
	5 Yr	51	36.34 ± 0.29	
	Total	259	36.36 ± 0.28	
5) After nap	1 Yr	38	36.23 ± 0.31 *	p<.05
	2 Yr	57	36.05 ± 0.24 * *	
	3 Yr	66	36.15 ± 0.28 * *	
	4 Yr	47	36.21 ± 0.27 *	
	5 Yr	51	36.33 ± 0.25	
	Total	259	36.18 ± 0.29	
6) Upon leaving the nursery	1 Yr	38	36.46 ± 0.28	p<.05
	2 Yr	57	36.39 ± 0.29	
	3 Yr	66	36.30 ± 0.35	
	4 Yr	47	36.40 ± 0.27	
	5 Yr	51	36.37 ± 0.30	
	Total	259	36.38 ± 0.31	
7) Before sleep	1 Yr	38	36.41 ± 0.33	p<.05
	2 Yr	57	36.37 ± 0.35	
	3 Yr	66	36.31 ± 0.31	
	4 Yr	47	36.28 ± 0.28	
	5 Yr	51	36.22 ± 0.33	
	Total	259	36.32 ± 0.33	
8) Time of going to sleep	1 Yr	38	36.17 ± 0.37	p<.05
	2 Yr	57	36.06 ± 0.40	
	3 Yr	66	36.10 ± 0.34	
	4 Yr	47	36.05 ± 0.25	
	5 Yr	51	36.03 ± 0.31	
	Total	259	36.08 ± 0.34	

One way ANOVA was used for comparisons between ages, and Bonferroni method for multiple comparisons
Asterisks (*) indicate p<.05

sleep.

For all ages, the temperature at the time of waking up was the lowest, and the body temperature rhythm was one with the temperature rising during the morning and falling during the afternoon until sleeping. The time period with the

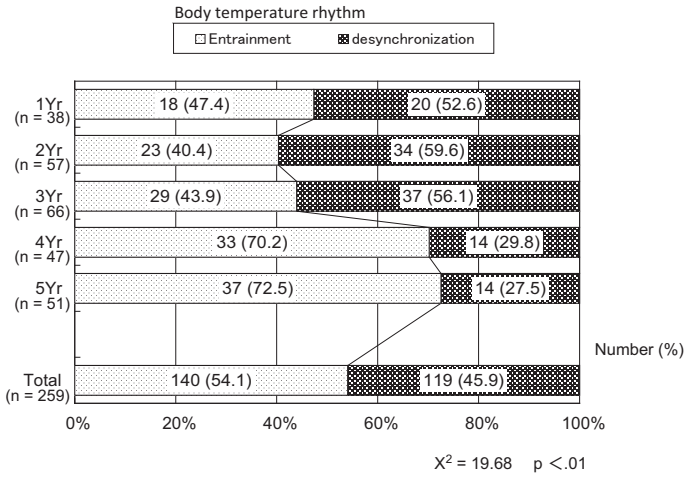

Fig. 1 The proportion of the body temperature rhythm

highest temperature was in the afternoon when leaving the nursery for one-, two-, and five-year-olds, and in the morning before lunch for three- and four-year-olds.

4. Entrainment of body temperature rhythm and desynchronization (Fig. 1)

The temperature rhythm was judged according to Criteria 1 to 4, based on the fluctuation of individual children's body temperatures within the day. The results showed that 140 (54.1%) children were included in the entrainment group and 119 (45.9%) children were included in the desynchronization group. The proportion of children in the entrainment group in each age group was 18 (47.4%) children for the one-year-olds, 23 (40.4%) children for the two-year-olds, 29 (43.9%) children for the three-year-olds, 33 (70.2%) children for the four-year-olds, and 37 (72.5%) children for the five-year-olds. Significant differences were observed between the age groups, and the proportion of children in the entrainment group was larger at the ages of 4 years and over.

5. The relationship between the body temperature rhythm and related factors (Table 5)

Regarding the relationship between body temperature rhythm and other factors, significant differences were observed for age in months, time of waking up, time of going to sleep, length of nighttime sleep, breakfast intake score, regularity of breakfast, and time sufficiency of breakfast. Children with entrained body temperature rhythms

Table 5. Body temperature rhythm and related factors

Factor		Entrainment (n = 140)	Desynchronization (n = 119)	Comparison between Body temperature rhythm
Age in months (months)		50.5 ± 18.1	43.0 ± 14.6	***
Kaup's index		15.8 ± 1.7	15.9 ± 1.4	n.s.
Sex	Male	69 (53.5)	60 (46.5)	n.s.
Number of children (%)	Female	71 (54.6)	59 (45.4)	
Time of Waking up		7:08 ± 32	7:31 ± 33	***
Time of going to sleep		21:43 ± 35	22:22 ± 44	***
Length of nighttime sleep		9.47 ± 0.72	9.13 ± 0.67	***
Sleeping environment	Dark	44 (51.8)	41 (48.2)	n.s.
Number of children (%)	Light	96 (55.2)	78 (44.8)	
No. of days child woke up wide awake		3.91 ± 1.44	3.60 ± 1.41	n.s.
No. of days the child woke autonomy		2.91 ± 1.77	2.67 ± 1.67	n.s.
Breakfast scores		3.32 ± 1.45	2.37 ± 1.67	***
Regularity of breakfast time	Regular	82 (48.2)	88 (51.8)	*
	Irregular	58 (65.2)	31 (34.8)	
Sufficiency of time for breakfast	Insufficient	36 (46.2)	42 (53.8)	*
	Sufficient	74 (62.7)	44 (37.3)	
Parents' child-rearing attitude	Good	76 (56.3)	59 (43.7)	n.s.
Cannot be said to be either/ Poor		64 (51.6)	60 (48.4)	

For the comparison of mean hours for each body temperature rhythm category, a t-test was used, and a χ^2 test was used for the comparison of proportions

Triple asterisks (***) indicate $p<.001$, double asterisks (**) indicate $p<.01$, and single asterisks (*) indicate $p<.05$

Table 6. Factors related to temperature rhythms in children (n = 259)

Factor	OR	95%CI for OR	P-value
Age in months (months)	0.969	0.952－0.987	p = 0.0005***
Time of Waking up	2.113	1.176－3.866	p = 0.0122*
Time of going to sleep	3.834	2.376－6.466	p < 0.0001***
Breakfast scores	0.853	0.773－1.032	p = 0.1129

Logistic regression analysis. Nagelkerke R^2=0.25.The dependent variables are the body temperature
rhythms: entrainment=1, desynchronization=0. OR,odds ratio; Cl,confidence interval.

had higher ages in months, earlier times of waking up and going to sleep, and longer length of nighttime sleep than children with desynchronization. Children with entrained body temperature rhythms had higher breakfast scores calculated from the contents of the breakfast and had more regular breakfast times, as well as more children having sufficient time for breakfast. No significant differences were observed for the gender of the children, physique index (Kaup's index), which is said to have an effect on rising temperatures, the sleeping environment, and the parents' attitude as assessed by the nursery teacher.

6. Factors related to temperature rhythms in children (Table 6)

A multiple logistic regression analysis was carried out with body temperature rhythm as a response variable, and using age in months, time of waking up, time of going to sleep, length of nighttime sleep, breakfast intake scores, regularity of breakfast time, and time sufficiency for breakfast, which were found to have significant differences in relation to body temperature rhythm, as explanatory variables.

When adjustment of items was carried out using a stepwise method (adopted at $p \leqq 0.25$), the adopted factors were age in months, time of waking up, time of going to sleep, and breakfast intake scores. When a multiple logistic regression analysis was carried out for the above items, the relationship with body temperature rhythm was observed for age in months, time of waking up, and time of going to sleep, and of these, the time of going to sleep had the strongest relationship.

7. Comparison between ages (Table 7)

The degree of relation of the lifestyle factors in terms of development was checked by carrying out the above analysis for each age and comparing the analysis results. For splitting subjects by age, children were categorized into younger children, aged 1－3, and older children, aged 4－5, based on previous studies[15], indicating that body temperature rhythms become the same as those of adults by the latter half of infancy. The results of this study showed that the proportion of entrained body temperature rhythms was higher from four years old. Out of the items adopted in the above analysis, age in months was excluded, while the items time of waking up, time of going to sleep, and breakfast intake score, were included, and odds ratios were compared. The highest odds ratio was found for time of going to sleep for both one- to three-year-olds and four- to five-year-olds, however, for the younger child group with one- to three-year-olds, a relationship was also observed for time of waking up.

Table 7. Factors related to temperature rhythms in children (Comparison between ages)

	Factor	OR	95%CI for OR	P-value	R^2
1－3Yr (n = 161)	Time of Waking up	2.223	1.077－4.726	p = 0.031*	0.22
	Time of going to sleep	3.636	1.978－7.065	p < 0.0001***	
	Breakfast scores	0.843	0.675－1.048	p = 0.124	
4－5Yr (n = 98)	Time of Waking up	1.599	0.576－4.565	p = 0.368	0.18
	Time of going to sleep	3.609	1.915－9.246	p = 0.0004***	
	Breakfast scores	0.810	0.516－1.166	p = 0.321	

Logistic regression analysis. The dependent variables are the body temperature rhythms: entrainment=1, desynchronization=0. OR,odds ratio; Cl,confidence interval.

Discussion

Approximately one-half of the subject children had their body temperature rhythms entrained, and the proportion was higher in four-year-olds and older. This result is as expected, considering that body temperature rhythm is held to be almost established by around the age of 5[23]; however, only approximately 70% of children had entrained body temperature rhythms. The difference observed between the body temperature rhythm entrainment group and desynchronization group in regards to the time the children went to sleep or woke up seems to suggest that undesirable lifestyles influence the entrainment of body temperature rhythms.

The results of the multivariate analysis, which was conducted with consideration for the relationship between the factors, found a relationship between body temperature rhythms with age in months, time of going to sleep, and time of waking up. Out of these, the strongest relationship was observed with time of going to sleep. The time children went to sleep showed larger fluctuations compared with the time children woke up. This is thought to be because the subjects were children who attended nurseries, resulting in relatively stable waking-up times on weekdays, whereas the times of going to sleep are more susceptible to individual lifestyle habits.

In previous studies, there have been reports that delayed time of going to sleep has an influence on other lifestyle rhythms; that the time of waking up, breakfast time, and dinner time for children who go to sleep late are significantly later than those for children who sleep earlier[24,25]; and that delays in times of going to sleep are related to decreases in children's appetite[26]. Additionally, going to sleep late has been found to be related to shortened sleeping hours, later dinner times, longer times spent watching television, and irregularities in waking times[20,21]. Therefore, it can be considered that the time children go to sleep is the most important factor in determining whether a child has good or bad lifestyle habits. As the lifestyle factor with the strongest relation on the entrainment of body temperature rhythm in this study was the time children went to sleep, it can be concluded that sleeping at an early time leads to the improvement of overall lifestyle habits, as well as the body temperature rhythm.

When the degree of relation by lifestyle factor was compared between ages, the time of going to sleep presented the highest odds ratio for both one- to three-year-olds and four- to five-year-olds. In the younger children group of one- to three-year-olds, a relationship was also observed with wake-up times, while no significant relationship was observed for four- to five-year-olds for this item. This seems to be related to length of nighttime sleep. It is normally the case that the earlier the time of waking up, the shorter the length of nighttime sleep. Since younger children need longer sleeping hours per day than older children, it is expected that younger children will not have sufficient nighttime sleep if they wake up early; however, in reality, these younger children sleep during afternoon naps, which help them get sufficient total sleeping hours. In contrast, older children who do not nap in the afternoon must make up for insufficient sleeping hours lost from going to sleep late by means of delaying the wake up time. As it is generally stated that the most important entrainment factor in adjusting the sleep-wake circadian rhythm is stimulation by morning light[22], waking at an early time is important in terms of the entrainment of rhythms. However, these findings may suggest that for Japanese children, who have significantly later times of going to sleep[27] compared with children in the rest of the world, the disadvantages of insufficient sleeping hours currently outdo the benefits of early waking.

Limitations of study and future issues

The study was conducted at the nursery schools that were selected via snowball sampling. Each target facility is an average authorized nursery school with approximately 90 to 120 children. Although efforts were taken to ensure that the home environment and age distribution of subjects were not disproportioned, the results of this study cannot be readily generalized. In order to check

body temperature rhythms, it is actually more desirable to measure body core temperatures; however, it is practically impossible to measure a healthy child's body core temperature accurately without interfering with their normal life for long periods of time, when multiple measurements are taken in a day. This is the reason why an electronic thermometer was used, as it provides a means for easy and safe measurements. However, the body temperature of children is less stable than that of adults, and is susceptible to environmental factors, such as ambient temperature and activity level. Since this study continued from June to October, it cannot be denied that factors, such as hours of sunlight and temperature, might have affected the body temperature rhythms of children. Therefore, additional investigations are required in order to provide a more precise evaluation of the measurements, such as attempting to make the environmental factors uniform, including temperature and humidity, adding children's activity levels as a study item, making body temperature measurement times uniform, and including the rate of temperature increases in the judgment criteria. Moreover, although the afternoon nap was not included in the analysis of this study due to a lack of reliability in the results, since it has been reported that the time to go to bed, which was most closely related to the body temperature rhythms, is related to the afternoon nap[28,29], the afternoon nap should be addressed in the future.

For lifestyle factors, this study was conducted for 5 days continuously to investigate the relationship between lifestyle factors and body temperature rhythms. However, with a cross-sectional short period study alone, there is a limit to being able to cover the actual circumstances of normal lifestyles. It is clear that nocturnal lifestyles are related to delays in wake-up times and children not eating breakfast, which lead to undesirable lifestyle habits, such as children having decreased activity levels during the day and increased hours spent watching television, which create a vicious cycle. Therefore, future longitudinal studies are required that should include viewpoints on the long-term effects of these lifestyle habits being repeated in childhood.

While children need to depend on adults in every aspect of their lives, priority is often given to adults' lives in the present society. The author intends to use the results of this study to enable parents and adults involved with children to realize the significance of lifestyle habits in the development of children.

Conclusion

Approximately 50% of children had entrained body temperature rhythms, and the proportion increased for children 4 years old and older. Body temperature rhythms were related to the time of going to sleep, the time of waking up, and their age in months, and the body temperature rhythms showed higher entrainment for earlier times of going to sleep and waking up, as well as for higher ages in months. The factor with the strongest relationship was the time of going to sleep. The time of going to sleep had the strongest relationship with the body temperature rhythm for both the younger children and the older children. In addition, a relationship was observed for the time of waking up among the younger children.

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子どもの体温リズムに関連する生活要因の検討

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要　　旨

生活要因と幼児の体温リズムの関連を明らかにするために、１～５歳の保育園児254名を対象に調査を行った。

調査の内容は、体温リズムの測定および保護者への自記式質問紙とday-by-day plot法による睡眠覚醒リズム、食事等の生活状況調査である。

幼児の睡眠状況は、就寝時刻は22時前後、起床時刻は７時20分、体温リズムが同調していた子どもは約５割で、４歳児以上になるとその割合が高くなっていた。

体温リズムには就寝時刻、起床時刻、児の月齢が関連し、就寝時刻、起床時刻が早いほど、月齢が高いほど体温リズムは同調しており、最も関連の強い要因は就寝時刻であった。

年少児群と年長児群のいずれも最も体温リズムと関連があったのは就寝時刻であったが、年少児群では起床時刻にも関連が認められた。