

Five School Days Successive 24 Hours Measurement of Physical Activity and Sleep of Four Years Old Children's Attending Nursery School of Japan

Kazuko Kawano, Yumeka Seno, Shigenori Shirouzu, IEEE Member, Takeo Masaki and Hisanobu Sugano, IEEE Member

Kazuko Kawano is superintendent of Yokohama Nazareth Nursery School, Educational Foundation ShionGakuen, Aobaku, Yokohama, 227-0054, (e-mail:kawano-shion.outlook.jp)

Yumeka Seno is with Educational Foundation ShionGakuen, Aobaku, Yokohama, 227-0033, (email:yumeka-shion.outlook.jp)

Shigenori Shirouzu and Takeo Masaki are with the Japanese Research Institute of Healthcare and Education, Nerima, Tokyo 179-0076, Japan, (phone: +81-80-3080-7158; e-mail: shirouzu_vista@live.jp).

Hisanobu Suano is an Emeritus professor of University of Occupational and Environmental Health, Japan, Kitakyushu, Fukuoka, 807-8555, Japan, (e-mail: sugano-h@rr.ij4u.or.jp).

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corresponding Author:

Kazuko Kawano

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ABSTRACT

There are two quite different types of preschool, kindergarten and nursery school (NS), in Japan. Must have nap time etc., nursery school operation is strongly restricted by the government, and these restrictions are thought to decrease children's physical activity (PA) at NS, increase late night PA, make sleep start time late and lower the quality of sleep. To overcome these weak points of NS, Yokohama Nazareth NS has been making many efforts to increase children's PA at NS. We measured nursery schoolers' PA and sleep behavior, and compared them with those of kindergarteners' previously reported.

Introduction:

Ten percent of the world's school-aged children are estimated to be carrying excess body fat, with an increased risk for developing chronic disease [1]. Now, obesity of children is a rising crisis in public health [1]. In the United States, many experts have recommended that public health initiatives to prevent obesity should begin with youngest children [2]. Since it seems certain that decreased physical activity is contributing to the increase in childhood overweight and obesity, public health authorities have issued recommendations for promotion of physical activity among children and adolescents [2]. There are two quite different types of preschool, kindergarten (KG)[3] and nursery school (NS) [4], in Japan. They are governed by

different laws, School Education Law (KG) and Child Welfare Law (NS). KG educates preschoolers, while NS nurses children instead of their parents. Existence of the nap time around 90 minutes from 2:00 p.m. requested by the Child Welfare Law makes daily life activity of the same age nursery schoolers (NSRs) and kindergarteners (KGRs) quite different. Existence of the nap time for 4 or 5 years-old child has been criticized as the reasons of their low quality nocturnal sleep, late start time and short duration. [5]. Recently, NSRs lesser amount of physical activities (PA) during at NS than those of KGRs during at KG, and the existence of large PA at late night were reported [6].

Early childhood was a period of intense development and a critical time for acquiring healthy life style and sleep habits. Hence, insufficient PA or poor quality sleep at early childhood negatively affects their whole subsequent life [7-10].

NS operation is strongly restricted by the government [11]. Due to the preference of working parents, NSs tended to locate at convenient place, such as at downtown and near the station, where land price was high. Hence most of nursery schools are small size (numbers of children, size of school buildings) with no play garden. They cannot have school bus, either. Hence, they can let children play only inside of their narrow institution or parks of the neighborhood which can go on foot.

These shortages of playing places together with the decrease of the playing time due to the existence of nap time decrease children's PA during at NS, increase late night PA, make sleep start time late and lower the quality of sleep [5, 6].

On the other hand, KGs can operate comparatively freely. Since they can have school bus, they can provide larger buildings and playing gardens at the place with low land cost. Furthermore, it is also possible to have playing places for children distant from the KG, and carry children with school bus. For example, Educational Foundation ShionGakuen (SG), Nazareth Kindergarten (NKG, Yokohama, Japan), sufficient amount of the PA [12] and the good sleep behavior of 4 years-old children [13] were reported recently, has a hill with natural woodland named Karanko Mt for this purpose.

In the same area with NKG (upper-class residential area in the Tokyo suburbs), SG is also managing a NS (Yokohama Nazareth nursery school, YNS) at the place nearer to the train station. To solve the weak point of NS, small amount of PA during NS, SG is performing several efforts including to bring NSRs to Karanko Mt., NKG's playground and larger park distant from NS to play with NKGs school bus. In this study, We measured nursery schoolers' PA and sleep behavior, and compared them with those of kindergarteners' previously reported. As same with previous reports for KGRs [12, 13], 24 hour's PA and sleep behaviors of 4 years old NSRs were measured with small and light weight wearable ECG and acceleration measuring device, M-BIT.

Measurement And Analysis:

A. Measurement of children:

Subjects were 4 years-old (y.o.) children. Since total number of NSRs was small as around 50 with wide range of age as from 0 y.o. to 5 y.o. Numbers of 4 y.o. children were only 9 in total. They were all normal and healthy.

In the case of a nursery school without playing garden, children's activity are usually indoor playing, walking to the nearest small park which is substitution of playing garden and outdoor playing there, and walks of the neighborhood. The park and course of walks must be register to the local government. In addition to these, YNS brought children to NKG's playing garden, Karanko Mt. and a distant larger park to play. Since at where let children play were changed by the day of a week, large daily difference of PA was expected.

Although children come to and leave from NS with their parents, they may walk from their home or nearest train station, or they brought by a car or a bicycle. Due to parents' convenience, their method of coming and leaving NS changes frequently. A large influence to the daily PA of the difference of these methods was expected, too.

In order to evaluate the change of children's PA and sleep behavior due to the change of such a daily program, etc., we performed five school days successive 24 hours measurement with M-BIT from Wednesday morning (WM) to next WM.

In WM after all the children arrived NS, we attached them M-BIT and started the measurement. In Thursday morning around the same time, we exchanged M-BITs to new ones. For Friday's measurement, we asked their parents to detach M-BIT, and collect them in Monday morning. In the case of accidental detach of M-BIT during measurement, we asked parents to re-attach M-BIT. Thus, we explained the details of research to parents, and obtained their complete cooperation. This study was approved by the Ethics Committee of the Japanese Research Institute of Healthcare and Education.

B. M-Bit:

M-BIT allows 25 hours' measurement with sampling frequency of 128 Hz (ECG) and 1 Hz (3-axes acceleration) [1, 2]. In the scope of this paper, we did not use ECG data.

C. Estimation of sleep area:

Our epoch duration for analysis was 1 minute. Posture vectors of thorax, M-BIT attaching portion, were derived from 3-axes acceleration. We obtained their epoch averages, and searched “in bed” area, the area where horizontal postures of up-down direction were continued. Within in bed area, we classified sleeping posture as supine, left lateral, prone, right lateral, and obtained their distributions and numbers of changing. For sleep/awake estimation, we classified epochs with and without body movement at first. For each sampling, we selected “sampling difference” as maximum value among 3-axes difference of acceleration with previous sampling, and put “epoch difference (EPD)” as the epoch maximum of sampling difference. We set threshold for with or without movement based on the average of EPD within whole analyzed area, and judged epoch without movement (ENMV) when EPD was less than the threshold. Then we searched “in active areas (IAAs)”, areas where ENMV were continued, and combined two successive IAAs if duration of separation was one epoch or average of ENMV during separation was less than four times the threshold. Finally, we selected sleep area among these IAA, details for this selection is publicly available [14].

D. Physical Activity:

As the measure of physical activity (MPA), we resampled acceleration vectors with 0.1Hz, and obtained epoch summations of the difference of the of acceleration vector’s length of two successive vectors. Using previously reported relationship between MPA and METs, we estimated MEYs from MPA.

We obtained MPA of all the awake epochs, then we classified awake epochs to four PA category according to the estimated METs level from MPA as sedentary PA (below 1.5 METs), light PA (1.5 METs or above, below 3 METs), moderate-to-vigorous PA (MVPA) (3 METs or above, below 6METs) and vigorous PA (VPA) (6 METs or above). We counted the numbers of epochs belong these four PA category and expressed PAs with these numbers. Since only MVPA and VPA level PAs were effective in developing children’s motor skill and cardiopulmonary function, we called them as effective level PA (EFEPA). For detailed analysis of children’s PA, we obtained hourly

percentages of EFEPA epochs for every 60 minutes from 10:00 to 34:00 (10:00 at the next day) and called it PA pattern.. For the sake of convenience, we labeled these hourly percentages by the end time of each 60 minutes.

E. Statistical analysis:

We used free software R (Ver.2.14.2) [15] for the statistical analysis. Since there was no significant difference between boys and girls in our previous study, we did not divide them in this study. We performed one-way ANOVA for PAs and sleep parameters with measurement days. We set significance level as p value less than 0.05.

Results And Discussion:

A. Sleep awake and PA patterns of characteristic children

Five day’s sleep awake and PA patterns of characteristic children are shown in Figs. 1-3. Here, light gray and gray colors indicate awake and sleep area, and solid lines are PA patterns. As mentioned above, there are 90 minutes nap times around 14:00. Not the all children sleep at nap time in the case of 4 y.o. children, they forced to lay them down to the floor and not to move. Reflecting these situations, almost all the children showed very low EFEPA percentages in this time area.

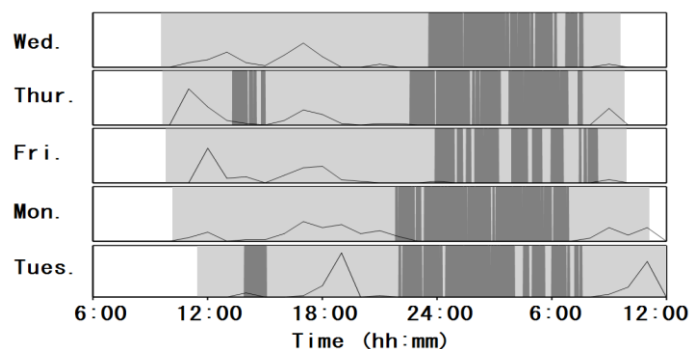


Figure 1 Sleep awake and PA patterns of Child_C. (Light Gray: awake, Gray: sleep, solid line PA pattern)

In the case of Child-C, as shown in Fig.1, we could obtain data of sufficient length in all the five days. He slept at nap time only on Thursday and Tuesday. In nocturnal sleep on Friday, many awake after sleep onset were observed, hence sleep efficiency of this sleep was low (0.586) and sleep duration was short (5.5 hours). Since the participation to and continuation of the measurement depended children’s and their

parents' will, the number of children with full results similar to Child_C were small.

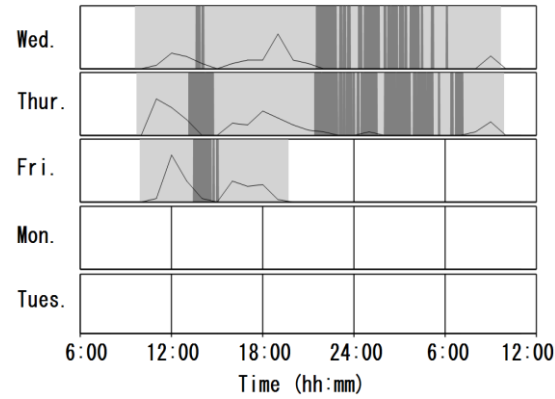


Figure 2 Sleep awake and PA patterns of Child_H (Light Gray: awake, Gray: sleep, solid line PA pattern)

Child_H refused the measurement of nocturnal sleep on Friday as saying “I know my sleep

	n	Bedtime (h)	Times in Bed (hours)	Sleep latency (min)	Sleep duration (hours)	No of awake after sleep onset	Sleep efficiency	No of postural change	Total sleep duration (hours)
<i>nursery school</i>									
Wed.	6	22.0±1.0	9.2±1.2	14.7±13.2	7.7±1.5	12.2±3.3	0.834±0.109	31.3±7.6	8.1±1.4
Thur.	7	21.5±0.9	9.7±1.0	26.0±18.3	8.1±1.0	12.4±3.5	0.830±0.046	32.3±19.3	9.4±1.1
Fri.	7	21.0±1.2	9.9±0.8	31.9±20.0	7.8±1.4	12.7±2.9	0.783±0.096	25.1±8.5	8.7±1.6
Mon.	3	23.0±2.6	8.5±3.2	13.3±1.5	7.1±2.7	14.7±7.1	0.828±0.025	25.3±15.0	8.5±0.5
Tues.	3	21.8±0.4	9.8±0.5	12.3±2.5	8.2±0.4	15.0±2.6	0.830±0.054	33.0±8.5	9.0±0.7
total	26	22.0±1.2	9.5±1.3	21.9±16.7	7.8±1.6	13.0±3.6	0.818±0.076	29.4±12.4	8.8±1.3
<i>kindergarten</i>									
L day	32	21.3±1.2	10.0±1.1	17.9±17.1	8.4±0.7	17.3±4.4	0.858±0.068	28.3±10.9	8.4±0.7
N day	26	21.6±1.2	9.9±0.8	15.0±11.1	8.5±0.8	16.8±5.5	0.872±0.066	29.8±9.4	8.5±0.8

behavior is not good. I do not want to be measured it”. As shown in Fig.2, his two nocturnal sleeps were low quality with many awakes after sleep onsets (sleep durations: 5.8 and 6.8 hours, sleep efficiencies: 0.621 and 0.768). Here, he took naps all the measured three days.

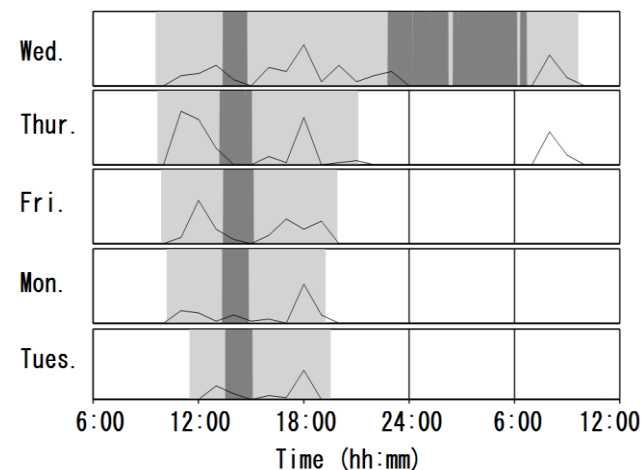


Figure 3 Sleep awake and PA patterns of Child_F (Light Gray: awake, Gray: sleep, solid line PA pattern) In the case of Child_F, although he started measurement all the five days, he detached M-BIT before bedtime from Thursday as shown in Fig.3. In the Thursday's measurement, he re-attached M-BIT after wake up and recorded morning activities. He slept at nap time all the day. By these situation, numbers of children from whom the data of sufficient length including the whole sleep at night and a physical activity of the next morning having been obtained were 6 (Wednesday), 8 (Thursday), 8 (Friday), 3 (Monday) and 3 (Tuesday), respectively.

B. Comparison of PA patterns of Thursday of all the children :

In Fig.4, PA patterns of Thursday, the day children brought to Karanko Mt. by bus, of all the children were shown together with those of KGRs' averages of Lday and Nday, with and without playing at Karanko Mt. During playing Karanko Mt. (11-12), PAs of all the NSRs were equally large level, and also same level with those of KGR's. However, at 14-15, KGRs show large PA by after KG program playing at the garden, while those of NSRs were equally 0 levels due to nap time. After 14-15 time zones, KGRs PA gradually decrease. In the case of NSRs, although large peaks around 18 were walking to home from NS, there were other large activities after peak at 18 and in some children at late night too.

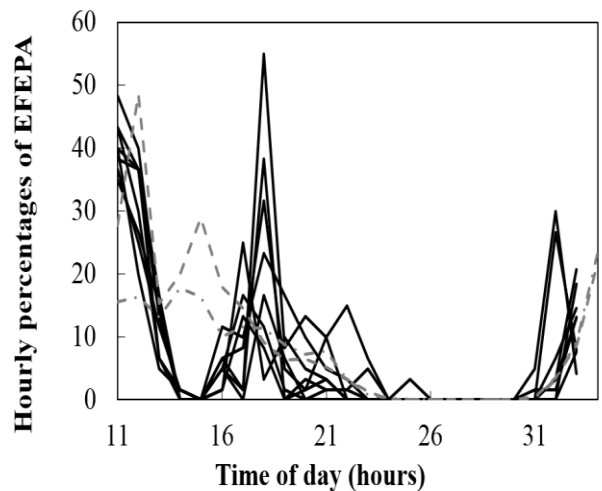


Figure 4 PA patterns of Karanko Mt. day of all the NSRs. (Black solid lines: NSRs, Gray dotted line: KGRs Lday, Gray broken line: KGRs Nday) Very small level of PA of nap time, and large level PA after NS and night were observed all the measured day.

C. Physical Activities:

PAs were summarized in Table I. Since one way ANOVA for PAs with measurement day showed no significance, we united them to one group and compared them to KGRs N day and L day. All the MVPA ($F_{(2, 81)}=16.78$), VPA ($F_{(2, 81)}=11.48$) and EFEPa ($F_{(2, 81)}=17.57$) were significant. Multiple comparisons revealed that all the MVPA, VPA and EFEPa were significantly smaller than those of KGR's Lday and no significant difference with those of Nday.

TABLE I. PHYSICAL ACTIVITIES

	N	MVPA	VPA	EFEPa
<i>nursery school</i>				
Wed.	6	66.0±14.1	23.3±5.1	89.3±17.8
Thur.	7	85.1±18.6	23.1±9.2	108.3±26.6
Fri.	7	67.9±22.8	27.4±11.7	95.3±29.9
Mon.	3	64.7±15.9	30.0±1.7	94.7±16.9
Tues.	3	80.7±17.8	26.3±3.8	107.0±19.9
total	26	73.2±19.2	25.5±8.1	98.7±23.7
<i>kindergarten</i>				
L day	32	102.0±18.9	38.8±16.9	140.7±31.7
N day	26	82.6±26.5	21.7±9.9	104.3±34.5

Since Nday of KGR's were rainy day [12], and KGR's PA were concentrated during at KG and no large PA at night in Nday too, we have to conclude that PAs of NSRs' at NS were still smaller than those of KGRs. YNS should make more efforts to increase children's PA during at NS, for example, introducing indoor skipping time .

D. Sleep Parameters:

Nocturnal sleep parameters together with total sleep durations during measurement were summarized in Table II. Since one way ANOVA for parameters with measurement day showed no significance, we united them to one group and compared them to KGRs Nday and Lday.

Only, numbers of awake after sleep onset (NASO) ($F_{(2, 81)}=9.69$) and sleep efficiency ($F_{(2, 81)}=3.81$) were significant. NSR's no of awake after sleep onset and sleep efficiency were significantly small than those of KDR's Lday and Nday.

Conclusion:

NSRs PA were significantly smaller than those of KDS's Lday and no significant difference with KDR's Nday. However, since NSRs showed large PA after NS and late night, PAs at NS were still smaller than those of KGRs. Sleep efficiency of nocturnal sleep was significantly small too.

The influence of existence of nap time, no activity time zone is very large. It is desirable to stop making nap time in daily program of NS [5, 6]. However, due to strong restriction from government [1, 12], NS without nap for 4 and 5 y.o. children are difficult goal to achieve. Right now, YNS should make more efforts to increase NSRs' PA. Due to the large individual difference of daily sleep parameters and small numbers of total and daily measured children, the some results of statistical comparison of sleep parameters became unclear. Furthermore, we could not evaluate daily differences, what kind of effort was more effective, statistically, After this study, YNS has been further making efforts to increase children's PA at NS. We are planning to next measurement, with more cooperation with children and parents by more explanation of significance and importance of our study to them.

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