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JOURNAL OF SLEEP AND SLEEEP DISORDER RESEARCH
ISSN NO: Coming Soon

Review Article
DOI : 10.14302/ISSN.2574-4518.jsdr-16-1413

Intervention Study to Improve Meal Habit, Sleep Habit, Circadian Typology and School Marks in Japanese Elementary School Students

Hitomi Takeuchi[1], Mizuka Nakao[2], Wataru Kurose[2], Takahiro Kawada[3], Teruki Noji[3], Miyo Nakade[4], Fujiko Tsuji[1], Mirada Krejci[5], Tetsuo Harada[1,*]

[1]Laboratory of Environmental Physiology, Graduate School of Integrated Arts and Sciences, Kochi University

[2]Tochi Elementary School, Kochi Prefecture

[3]Regional Collaboration Center, Kochi University

[4]Department of Nutrition Management, Faculty of Health and Nutrition, Tokai-Gakuen University

[5]Palestra University, Physical Education and Sports

ABSTRACT

Purpose: An intervention program called "Super Meal Education Program" was supported by Japanese Ministry of Arts, Sports, Sciences and Education. This program was implemented to improve meal habit and sleep habit and also to improve academic marks at school by Japanese compulsory schools students. The effects of the intervention were evaluated by comparing an integrated questionnaire study held both before and after the intervention of a half year.

Method: The intervention program consists of a lecture on sleep health and diurnal rhythms of children by an university professor, a series of lectures and practical classes by elementary school teachers on foods which can be collected nearby, and also practical courses as excursions to learn traditional meals and several foods resources which are products nearby. Integrated questionnaire study and also government official academic achievement test were performed before and after the intervention 6 months in May and November, 2015. An integrated questionnaire was administrated to elementary school students of grades 1 to 6 (7-12 years old). For the younger students aged 6-9 years old, parents (mostly mothers) answered the questionnaire instead of their children. The integrated questionnaire included questions on the diurnal type scale (DTS), sleep habits, meal habits, and other questions on their environments and habits.

Result: The rate of answer to the questionnaire was more than 95% and the number of data was 295 before and 286 after the intervention. In the histogram on distribution of the diurnal type scale scores (DTS) before intervention, 25 % of evening-typed students significantly shifted to significantly more morning-typed persons after that ($p<0.001$). There was significantly negative correlation between DTS scores before intervention and the amount of increased change in DTS during the intervention period ($r=-390$, $r<0.001$). For all students in the elementary school, there were no significant changes in sleep quality, bedtime in weekdays, wake up time and sleep hours before and after the intervention period. There was negative correlation between sleep hours in weekday before intervention and increased amount in sleep hours before and after that ($r=-0.545$, $p<0.001$). The longer the sleep hours become during intervention, the better the academic achievement mark was after the intervention (students in the second, third and fifth grades: $r=0.369$, $p<0.01$) in mathematics mark.

Conclusion: At least for the students who had been originally evening-typed, the intervention on meal habits may be effective for longer sleep hours and improved school achievement marking.

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Corresponding author: Tetsuo Harada, Laboratory of Environmental Physiology, Graduate School of Integrated Arts and Sciences, Kochi University, Kochi, 780-8520, Japan, Tel: +81-88-8448410. Fax: +81-88-8448453

Keywords: academic achievement mark, sleep habits, circadian typology, elementary school students, critical hours of 9 hours for better mark

Received : 24 Dec, 2016 **Accepted:** 28 Mar, 2017 **Published** 21 Jul, 2017

Introduction

In accordance with the 24 hours commercialization society which is rapidly going on in current Japanese society which gives children new environmental situations as zeitgebers. Convenient sores are very common in Japanese society and they count more than 20 shops in a small society with 300,000 population, Kochi city for example and smart phones distribute to 98% of junior high school students affiliated to Faculty of Education, Kochi University. Such current situation means that clear light-dark cycles and meals regularity on the times of day tend to disappear for the entrainment of their circadian clocks. According to such environments to children, night activity is supposed to be in progress and also lead to short night sleep hours due to late bedtime and early get-up time because of school and shifting to evening-typed life.

Due to the circumstances for Japanese children, some intervention program is needed for promotion of physical and mental health of Japanese children. Mental health has strong links to circadian typology: lower mental health like as depression can be associated with evening-typed life [1-7]. Because the circadian typology links to mental health, some intervention might be effective for preventing some mental problems in children [8]. However, such intervention studies for small children attending elementary school or younger are limited to a few ones.

Quach et al. [9] reported the intervention project called "Sleep Well Be Well". This project included individual consultations for families of children aged 5-6 years who had night sleep problems on screening. Gruber et al. [10] reported a project called "Sleep for Success" to improve sleep health and academic achievement. This project was a whole-school intervention involving sleep education for children, staff and parents. The participants of this project were children aged 7-11 years. This project used objective and subjective measurements of sleep. Sleep duration was elongated, sleep efficiency was improved and sleep latency was shorten due to the intervention. Another effective intervention program called "ACES" was developed for sleep health of adolescents and younger children [11]. Participants of 9-10 years were chosen because of no daytime naps already in this age [12].

However, there have been only a few studies on an intervention study including breakfast intervention (recommendation of taking protein resources) to improve academic achievement together with elongation of sleep hours for small children attending elementary schools so far. This study challenges to promote the academic mark and sleep habits of small children attending a model elementary school in Japan.

Participants and Methods

Description of the Study Participants Including Number of Participants

The integrated questionnaire and Government Academy Achievement Test held by Japanese Ministry of Education, Arts, Sports, Sciences and Technology were administered twice in May and November in 2015 to all students who attended an elementary school (33ºN, 133ºE) in Kochi Prefecture, Japan. Students of all grades of the 1st to 6th answered the integrated questionnaire. On the other hand, students in the second, third and 5th grades participated in the Government Academy Achievement Test. More than 95% of the students in this school, to which both of the integrated questionnaire and the Government Academy Achievement Test were administered, answered the both. The number of students who answered the integrated questionnaire was 40-55 in each of the first to the six grades of the elementary school. The questionnaire included, 1) Diurnal type score questionnaire (DTSQ) Torsval and Åkerstedt [13] constructed, 2) Questions on sleep habit (bedtime, wake-up time, sleep hours of both weekdays and

Table 1. Detailed contents of this intervention program, "Super Meal Educational Program" in accordance with time course

14 April 2015: Planting of larval rice into paddy fields in the field of the elementary school (5th grade students)
20 April 2015: Whole Japan Common Academic Questionnaire Marking Examination in Elementary School Subjects (2nd, 3rd and 5th grade students)
22 April 2015: Making a specific cubiculum for meals education with teachers and an guest university professor majoring in the meals education.
20 May 2015: Research class entitled "Welcome to 'Yamamoto plum restaurant and café' Chairs with Yamamoto-plum hand-made juice! " performed by a teachers and handy-capped children
25 and 26 May 2015: Practical class for making a cooked (only surface) Tuna-meat ("Katsuono-tataki") (4th grade students
27 May 2015: A special class for meal education entitled "Making a special and enjoyable menu!" (3rd grade students) in which breakfast recommended- in terms of nutritional components and type of food.
15-19 June 2016: Campaign week entitled "Let's finish to eat all food staffs supplied for lunch without foods which were left!"
26 June 2016: 1st Open Lecture for Meals Education entitled "Meals educations can promote academic achievement (Audiences: teachers and parents, Lecturer: a meals educator)
3 July 2017: Lecture on green pepper (Japanese name: Shishito) for parents and children
5 July 2017: A special class for meal education entitled "Let's think about vegetables which grow currently in the field!" (2nd grade students)
14 July 2017: A harvest festival for summer vegetables (2nd grade students)
2nd September 2017: A special lecture by an university professor entitled "Life habits and academic achievements" (5th grade students)
10 August 2017: A special lecture by an university professor majoring in sleep science and chronobiology entitled (On the correlation between life habits including sleep habits and academic achievements in elementary children (Audience: elementary school teachers)
14 August 2017: A practical meals education class: Harvest of rice from paddy fields in the elementary school field (5th grade students) in which breakfast recommended- in terms of nutritional components and type of food.
2 October 2017: A special lecture by an university professor entitled "Meals habit and academic achievement in elementary school students" (Audience: 5th grade students, teachers and parents) in which breakfast recommended- in terms of nutritional components and type of food.
28 October 2017: A special class for meal education entitled "Ideal meals habit which can be recommended for elementary school students" by an guest university professor (4th grade students) in which breakfast recommended- in terms of nutritional components and type of food.
2 November 2017: A special lecture for meals education entitled "Results of intervention study and relationship between meals habit and academic achievement of elementary school students" (Audience: teachers and parents) in which breakfast recommended- in terms of nutritional components and type of food.
18 November 2017: A special lecture of Japanese language course entitled "Think about Japanese culture. Searching on Japanese traditional sweets" by a elementary school teacher (5th grade students)
20 November 2017: A special practical course for meals education entitled "Let's pond cooked rice to make cakes ("Omochi-tsuki" in Japanese) (2nd grade students)

weekend), 3) Questions on mental health (irritation, anger, out of controlling emotion, depression) [14] [15].

Study Protocol

The intervention program consisted of a lecture on sleep health and diurnal rhythms of children by an university professor, a series of lectures and practical classes by elementary school teachers on foods which can be collected nearby, and also practical courses as excursions to learn traditional meals and several foods resources which are products nearby (Table 1).

The results of the integrated questionnaire which was the almost same could be compared before and after the intervention for a half year with identification of each participated student. However, detailed names were hidden for the analyzers and researchers from ethic view point.

Scales / Questionnaires used (Including Psychometric Properties and Method of Scoring)

The diurnal type scale (DTS) is the short version of Morningness-Eveningness scale Torsvall and Åkerstedt (1980) originally constructed. The DTS is used to measure an individual"s diurnal preference. Three of the 7 questions included in the DTS pertain to sleep onset timing in the evening, 3 to sleep offset timing in the morning, and 1 to peak timing of activity during the daytime. Each question allows for 1 choice from 4 choises (scored from 1 to 4). The DTS score is the sum of the 7 answers. The minimum possible score is 7 (extreme evening-type), and the maximum possible score is 28 (extreme morning-type). The questionnaire currently used most widely was constructed by Horne and Östberg (1976) and was based on an original questionnaire by Östberg consisting of 14 items which was revised and lengthened to 19 items. Correlations have been examined in M-E scores in the two versions: one by Torsvall and Åkerstedt (1980), the other by Horne and Östberg (1976). High correlation values were seen in junior high students aged 11-15 years (Ishihara, communication, r=0.673-0.762; Pearson"s correlation test: $p<0.001$)/ The high correlation was shown by 18-25 year old students in occupational and physical therapy training school (Harada unpublished, r=0.736; Pearson's correlation test: $p<0.001$). This provides validation of the Japanese version of the Torsvall and Åkerstedt questionnaire.

Statistics and Software used

Results of this study were analyzed with statistical software as SPSS 22 version (22.0 J for Windows; SPSS Inc., Chicago, IL, USA). $\chi 2$-test was used for categorized variables x categorized variables. Mann-Whitney U-test and Kruskal-Wallis test were used for categorized variables x ratio scale variables. Mental Health Index was expressed as sum of scales on 4 questions on mental health [irritation, anger, out of controlling emotion, depression, distributed from 4 (worst) to 16 (best) points] [16]. Wilcoxon test was used for pair-wised comparisons of the questionnaire data before and after the intervention.

Results

Sleep Habits and Meal Timing in Each Grade of Elementary School Children

The rate of answer to the questionnaire was more than 95% and the number of data was 295 before and 286 after the intervention. Bed time and sleep hours in week days in the third grade students before the intervention became slightly but significantly earlier and longer, respectively after the intervention (Table 2) . In the fifth grade, sleep hours in weed ends were significantly longer after the intervention (Table 3). In the fifth grade, the circadian phase of time when students became sleepy was shifted earlier by 20 minutes after the intervention. In the other grades, there were no significant differences between before and after the intervention in sleep habits and meal timing.

Diurnal Type Scales and Intervention

The distribution of the diurnal type scale scores before the intervention was similar to that after it (Figure 1). In the histogram on distribution of DTS before intervention, 25 % of evening-typed students significantly shifted to significantly more morning-typed persons (Kruskal wallis test, Morning types and medium types: $p>0.05$; Evening-types: $\chi 2$ value=37.01, df=2, $p<0.001$) (Figure 2). There was significantly negative correlation between DTS scores before intervention and the amount of increased change in DTS during the intervention period (Pearson"s correlation test: r=-0.390, $p<0.01$) (Figure 3).

Sleep Quality and Sleep Duration Improved During Intervention

In the first and fifth grades of the elementary school, students improved sleep quality after the intervention (Wilcoxon test: the first grade, z=2.218, p=0.027; the fifth grade, z=2.563, p=0.010) (Figure 4). There was negative correlation between sleep hours in weekday before intervention and increased of sleep hours during the intervention (r=-0.545, p<0.001).

Sleep Hours and Academic Achievement of Japanese Language and Mathematics

Before the intervention, significantly and clear higher mark in academic achievement of Japanese language appeared in the students who had more than 9 hours sleep than those who did less than 9 hours sleep (Mann-Whitney U-test: z=-2.30, p=0.021) (Figure 5). Improvement of academic achievement can be related to change of sleep hours. Students who had increased sleep hours after the intervention showed higher academic achievement marks in mathematics than those who did not (Mann-Whitney U-test: z=-2.355, p=0.018) (Figure 6). The longer the sleep hours in week days became, the higher the academic achievement mark in mathematics became after the intervention than that before it in the elementary school students aged 7-11 years old (Pearson's correlation test: r=0.369, p<0.01) (Figure 7).

Change in Breakfast Habit During the Intervention

The increase of regularity in breakfast time of day was related to the achievement of Japanese language (Mann-Whitney U-test: z=-2.029, p=0.042) (Figure 8). In the fourth grade, students improved the contents of breakfast with nutritionally well dishes including carbohydrates, protein and vitamins & minerals, after the intervention (Wilcoxon's test: the fourth grade, z=2.628, p=0.009).

For all students in the elementary school, there were no significant changes in sleep quality, bedtime in weekdays, wake up time and sleep hours during the intervention period (Tables 2 and 3). There was negative correlation between sleep hours in weekday before intervention and increased amount in sleep hours after that (Pearson's correlation test: r=-0.545, p<0.001).

Discussion

The intervention program for a half year seems to be effective for elementary school students to take better mark in academic achievements especially on mathematics through shifting them to "morning-typed" life. How does the morning-typed life link to better academic achievement in elementary school students? Three hypotheses would be possible as follows.

At first, sufficient REM sleep at the morning time

Table 2. Comparison of bedtime, wake up time and total sleep hours in weekdays in the students of an elementary school, before and after the intervention half-year

Grade	Bedtime in WD				Wake up time in WD				Sleep hours in WD			
	Mean		Wilcoxon test		Mean		Wilcoxon test		Mean		Wilcoxon test	
	Before	After	Z-value	P-value	Before	After	Z-value	P-value	Before	After	Z-value	P-value
1st	21.15	21.16	0.00	1.000	6.67	6.64	-1.03	0.301	9.53	9.48	-1.42	0.157
2nd	21,34	21.34	0.82	0.413	6.58	6.53	-0.29	0.775	9.24	9.19	-0.29	0.768
3rd	21.78	21.50	-1.96	0.051*	6.42	6.48	-0.87	0.385	8.65	8.98	-2.24	0.025*
4th	21.74	21.67	-0.62	0.536	6.47	6.52	-0.03	0.978	8.70	8.85	-0.95	0.351
5th	22.11	22.17	-0.03	0.978	6.43	6.45	-0.15	0.887	8.32	8.27	-0.37	0.712
6th	22.08	22.25	-1.81	0.071	6.35	6.50	-1.41	0.159	8.30	8.25	-0.72	0.472

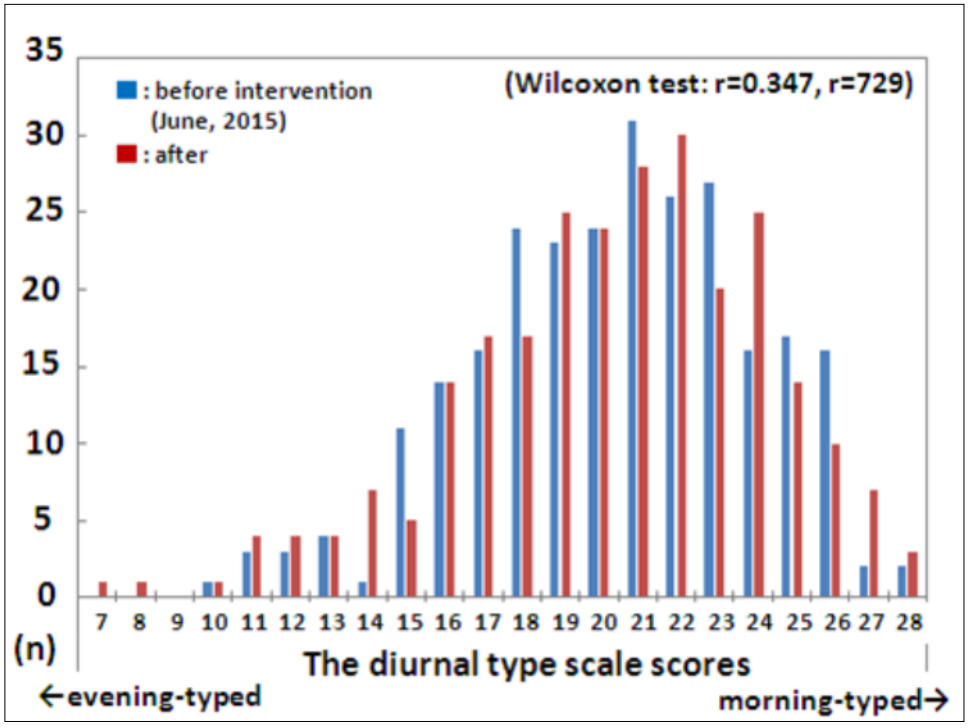

Figure 1: Distribution of circadian typology and comparison of those before and after the inter-vention a half year in elementary students aged 7 to 11 years old.

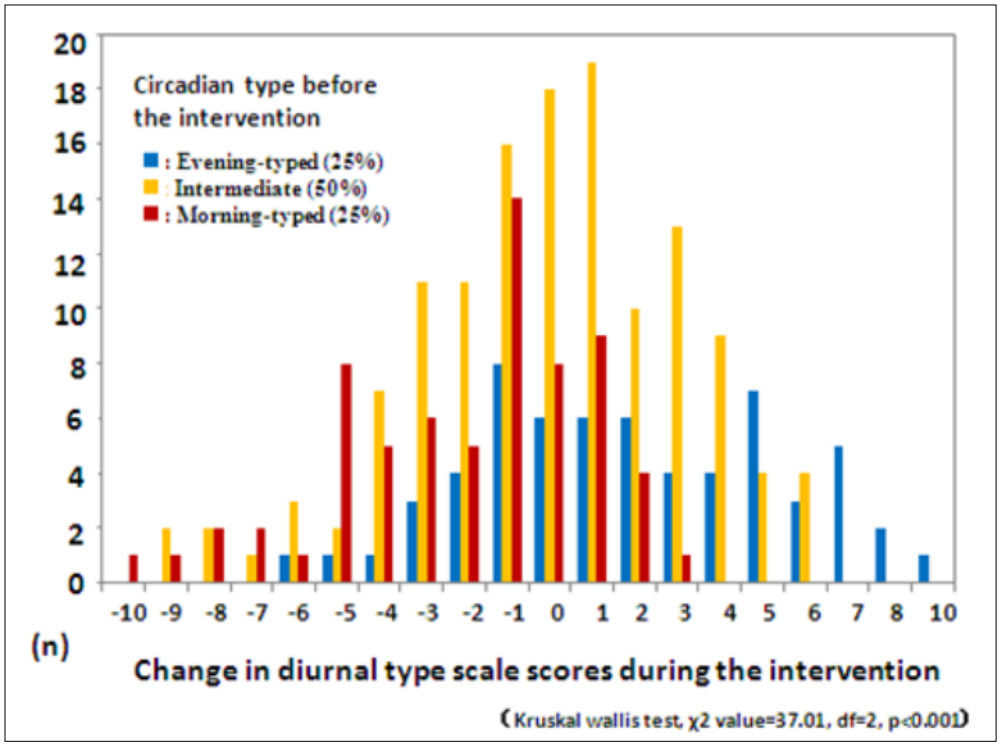

Figure 2: Change in the diurnal type scores during the intervention a half year in three chronotypes of morning-ness, medium and eveningness in May 2015 in elementary students aged 7 to 11 years old.

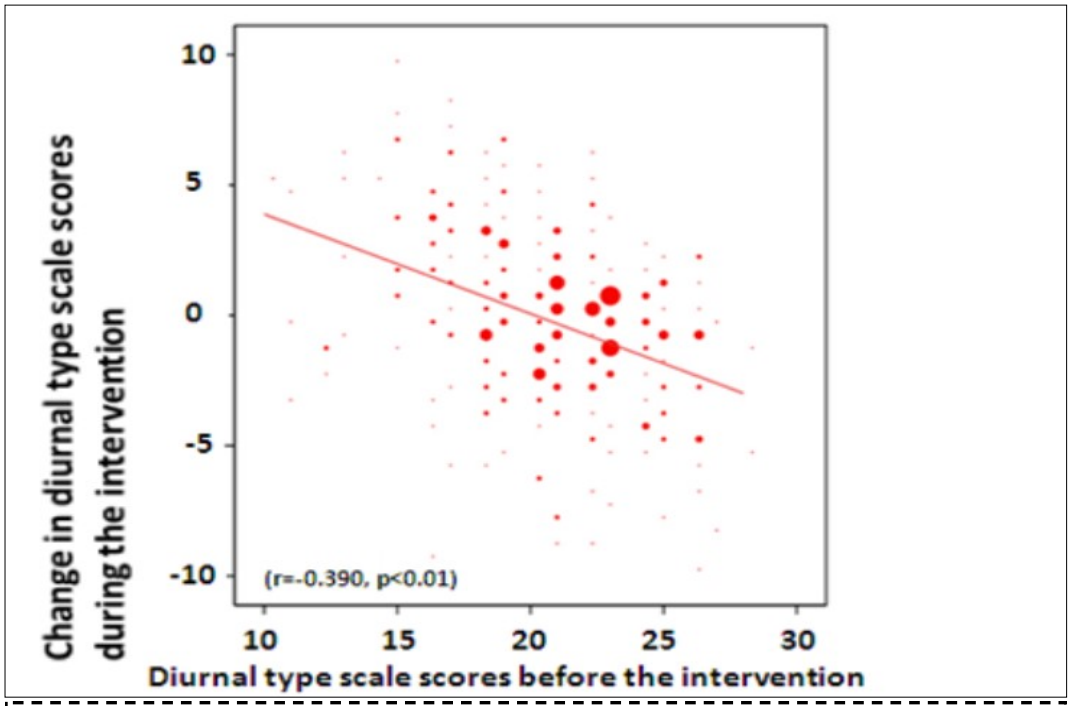

Figure 3: Negative correlation between the diur-nal type scale scores before the intervention and the changed value in the scores during the inter-vention a half year in the elementary students aged 7 to 11 years old. Evening-typed students shifted to more morning typed, whereas morning-typed ones to more evening typed.

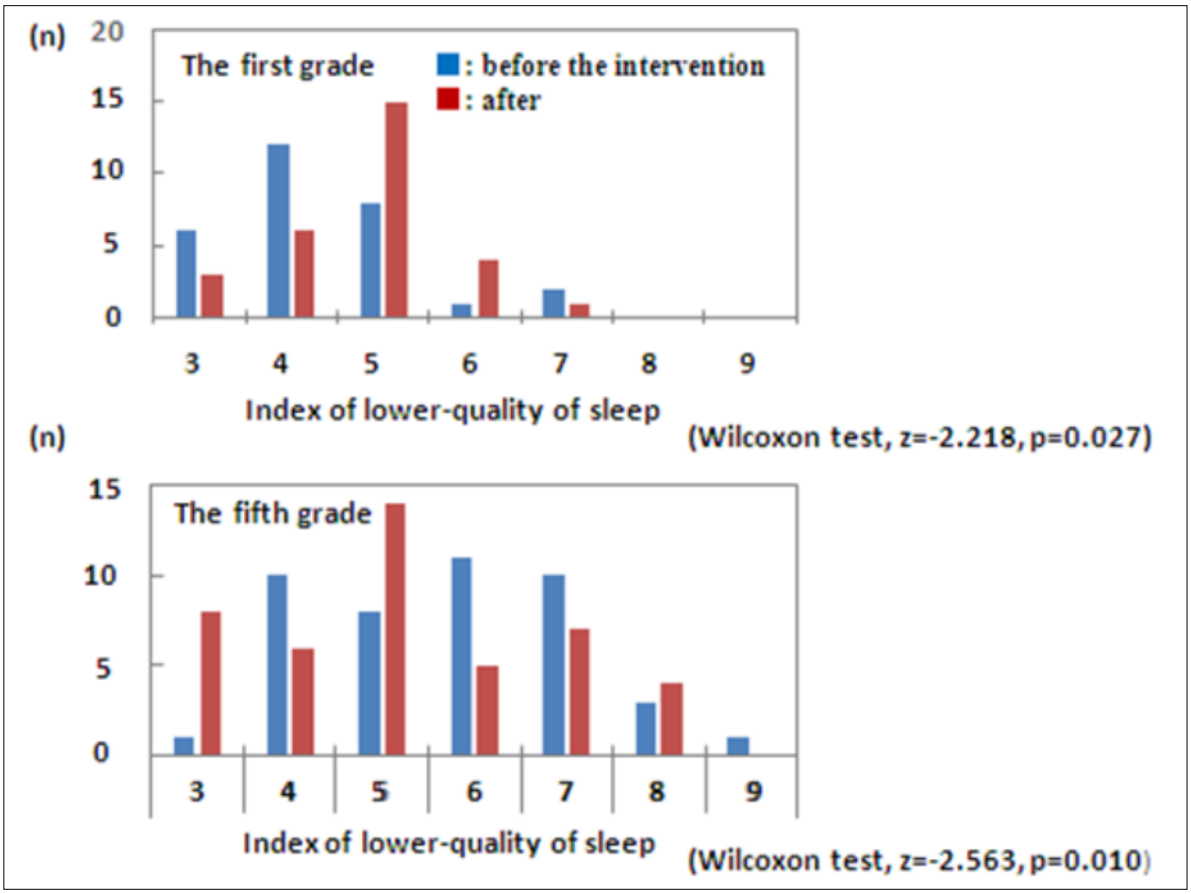

Figure 4: Improvement of sleep quality after the intervention in the students of the first grade and the fifth grade in an elementary school, Kochi city, Japan.

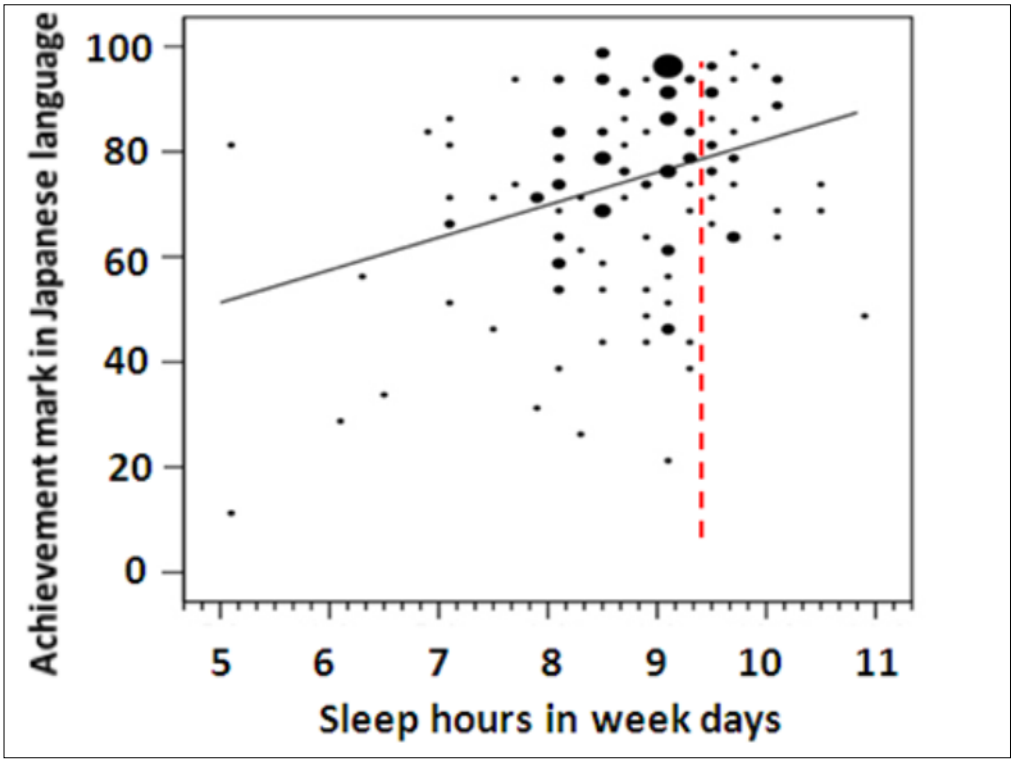

Figure 5: Relationship between sleep hours in week days and achievement mark in Japanese language of Japanese elementary students aged 7-11 (second, third and 5th grades students) (Mann-Whitney U-test: z=-2.30, p=0.021).

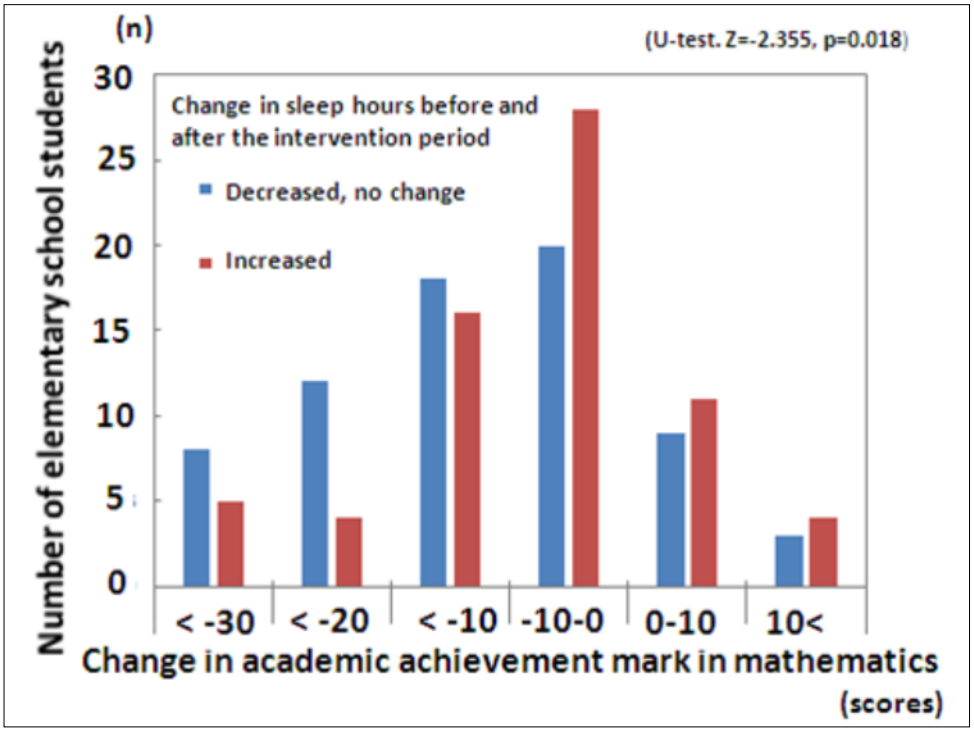

Figure 6: Increased hours of sleep might link to the improvement of academic achievement mark in mathematics of Japanese elementary students aged 7 to 11 years old.

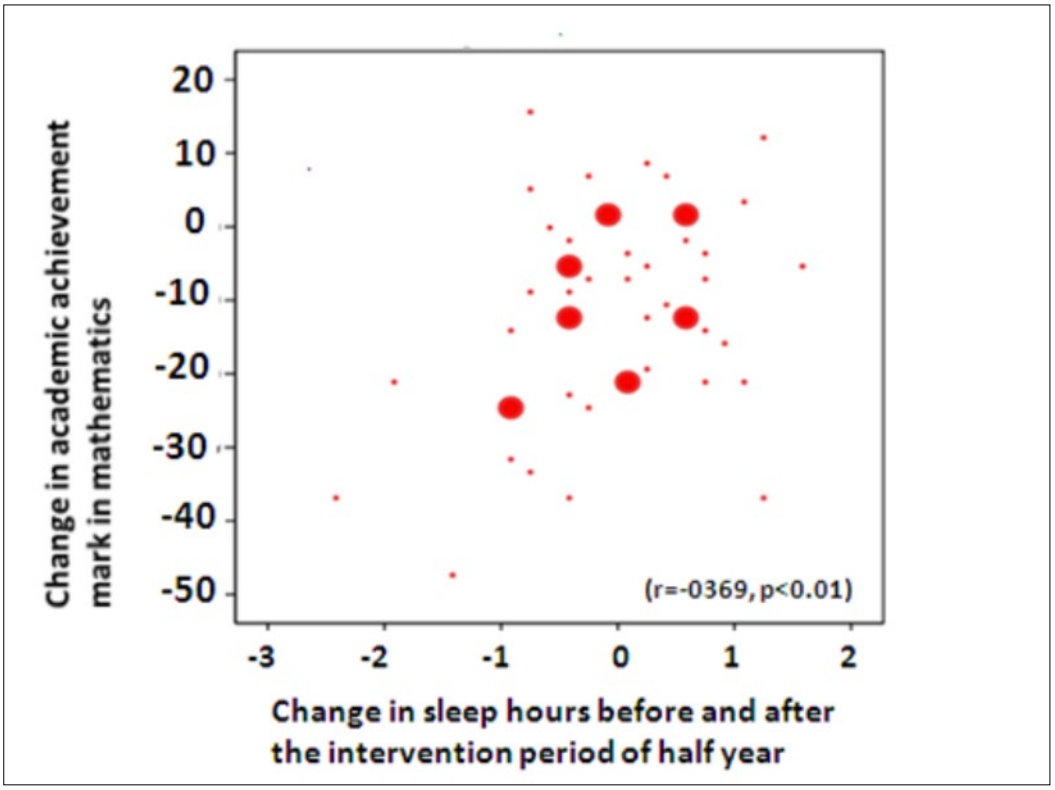

Figure 7: Positive correlation between change in academic achievement mark in mathematics and change in sleep hours during the half year intervention in Japanese elementary students aged 7 to 11 years old.

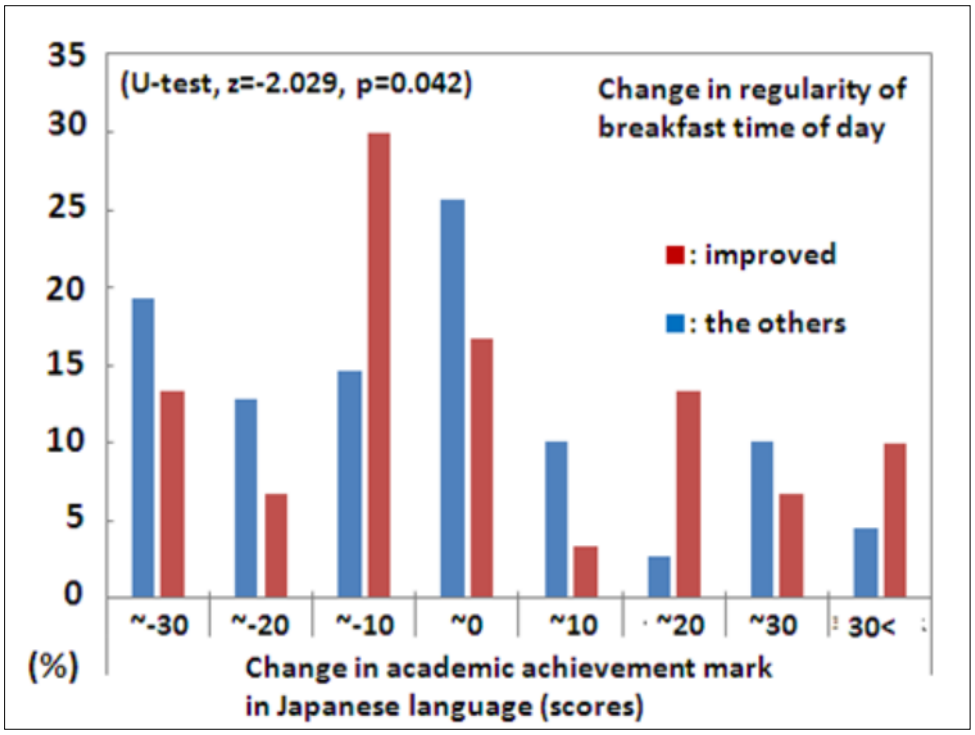

Figure 8: The regularity of breakfast time might link to the improvement of academic achievement mark of Japanese language in elementary students aged 7 to 11 years old.

Table 3: Comparison of breakfast time, dinner time and sleepy time at night in the students of an elementary school, before and after the intervention half-year.

Grade	Bedtime in WE				Wake up time in WE				Sleep hours in WE			
	Mean		Wilcoxon test		Mean		Wilcoxon test		Mean		Wilcoxon test	
	Before	After	Z-value	P-value	Before	After	Z-value	P-value	Before	After	Z-value	P-value
1st	21.59	21.63	-0.37	0.713	7.31	7.37	-0.44	0.664	9.73	9.74	-0.19	0.849
2nd	21,73	21.58	-2.92	0.003**	7.14	7.08	-0.64	0.524	9.41	9.50	-1.26	0.209
3rd	22.29	22.25	-0.18	0.861	7.62	7.31	-1.64	0.101	9.30	9.07	-1.04	0.229
4th	22.53	22.40	-0.27	0.790	7.50	7.50	-0.14	0.889	9.00	9.10	-0.54	0.558
5th	22.73	22.68	-0.87	0.381	7.75	8.03	-1.94	0.053	8.74	9.37	-2.19	0.029*
6th	22.56	23.03	-3.10	0.002**	7.93	8.10	-0.69	0.489	9.37	9.03	-2.04	0.042

zone can promote the fixation of new memories and also memory consolidation in school life. For sufficient REM sleep taken, morning-typed life is suitable, because two conditions for sufficient REM sleep to be taken are critical. The first condition is that a long sleep hours is needed before the long REM in the morning time zone like as 4-6 oclock. That means we need early bed time. Another condition is that there would be a "circadian time gate" which will open in the early morning zone for long REM sleep to occur. So, we have no choice and do morning-typed life.

Second, morning-typed life can promote better mental health [1-7]. Children who are morning-typed can challenge new academic contents in school with higher mental powers.

Third, morning-typed life can link to taking nutritionally rich breakfast, especially including protein resources like as (fermented) soy beans, eggs, fishes, and meats. The hypothesis is that the three conditions are needed for the phase advance of the circadian clocks of students. The first condition is that children should take protein sources of tryptophan and vitamin B6 at breakfast. The second one is that they should be exposed to sunlight after taking the nutritionally rich breakfast for serotonin synthesis. The third one is that they should be exposed to low temperature lights from night lighting for sufficient synthesis, at night, of melatonin from serotonin. These hormones work as natural anti-depression drugs (serotonin) and natural sleeping pills (melatonin) and function as inner zeitgebers for their circadian clock. They can finally make students more-morning typed and improve their mental health. The Higher serotonin level in daytime can be, the higher children's concentration on academic work at school is, leading to higher academic marks. Several studies support the hypothesis [16-20].

Conclusion

At least for the students who had been evening-typed, the intervention on meal habits may be effective for longer sleep hours and improved school achievement marking.

Acknowledgements

Thanks should be due to all the participants in this study. The following financial supports have been given to this study: 1) Fund from J-Milk „Meals and Education" (To T. Harada: 2013-2014), 2) Fund from J-Mild „Research Study to Promote Health by Milk and related foods" (To T. Harada: 2016-2017) and 3) Funds from Japan Society for the Promotion of Science (JSPS Grant Number JP 16K01871, 2016-2019: To H. Takeuchi).

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