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Circadian Rest-Activity Rhythm for Maintenance of Body Shape

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***Abstract*— A recently developed wearable device has gained attention in the area of self-discipline for the prevention of lifestyle-related diseases. The present study aimed to clarify the relationship between circadian rhythm and body shape change using actigraphy. Using a body shape vector, we classified 24 women in their 40s and 50s into 3 groups with different body shape changes. A circadian rhythm experiment was conducted on weekdays for 1 week with 24 healthy women. Amounts of activity of the non-dominant wrist and trunk, subjective evaluation of sleep quality, and subjective state of activity were surveyed. In order to maintain a constant body shape throughout life, a less sedentary lifestyle with more trunk movement during the day, getting adequate sleep at night, and having a varied sleep-wake cycle may be important factors.**

I. Introduction

A recently developed wearable device, called the "life recorder" [1], allows us to easily and unobtrusively obtain valuable physiological information over a long period. This device has gained attention in the area of self-discipline for the prevention of metabolic syndrome and other lifestyle-related diseases.

The present study focused on circadian rhythm, a biological rhythm based on an approximately 24-hour cycle including sleep-wake and rest-activity cycles. Circadian rhythm influences physiological and behavioral phenomena (e.g., body temperature, autonomic nervous system activity, and hormone release). Several studies have investigated circadian rhythm in subjects with sleep disorder under a variety of environmental conditions [2]. However, little is known about circadian rhythm in healthy people in normal daily situations.

If the relationship between circadian rhythm and body shape change is clarified, individuals may be able to identify an optimal circadian rhythm for daily living and thereby manage their lifestyle on their own. In addition, care focusing on circadian rhythm will be made possible in the maintenance of body shape.

The purpose of this study was to clarify the relationship between circadian rhythm and body shape change using actigraphy. The Human Research Science Center of Wacoal Corporation previously investigated body shape changes in the same woman over approximately 20 years. In the present study, we assigned body shape changes to a numerical scale and classified 24 women in their 40s and 50s into 3 groups. We then evaluated the daily life of each subject, focusing on circadian rhythm.

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II. Experimental Method

A. Subjects and Experimental Procedures

Twenty-four healthy, non-medicated women in their 40s and 50s were selected from the general public to participate in the experiment. We classified 24 women into 3 groups with different body shape changes. Then, the circadian rhythm experiment was conducted on weekdays for 1 week in July or August. All subjects wore two portable accelerometers, one on the non-dominant wrist and the other around the waist, at all times except when bathing and changing clothes. In addition, subjects completed the Oguri-Shirakawa-Azumi sleep inventory for the middle-aged and elderly (OSA MA version) [3] immediately after waking and kept a daily log. During the experimental period, subjects were instructed to go about their daily lives as usual. Written informed consent was obtained from each subject prior to participation in the study.

B. Experimental Device

Micro-mini Actigraph (Ambulatory Monitoring) was used to measure the amount of physical activity of the non-dominant wrist. The Actigraph, an acceleration-sensitive device resembling a wristwatch, was set to proportional integrating mode (low-PIM), which measures the intensity of a movement by integrating the deviations from 0 V every 0.1 s and stores the intensity once every minute.

Life-corder Plus (Suzuken) was used to measure the amount of physical activity of the trunk. The Life-corder measures the intensity (signal of 0.5 or 1 to 9) of movement every 4 s and stores the highest frequency signal for each 2-min period once every 2 min. The level of intensity is recorded on a scale of 1 (lowest intensity) to 9 (maximum intensity).

OSA is a quantitative index that evaluates five factors: the first factor is sleepiness on waking, the second factor is initiation and maintenance of sleep, the third factor is frequency of dreaming, the fourth factor is recovery from fatigue, and the fifth factor is sleep length. OSA contains 16 questions to evaluate subjective sleepiness and is completed immediately after waking.

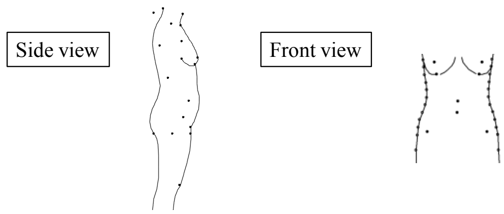

Fig. 1. Described silhouette image using the body shape vector.

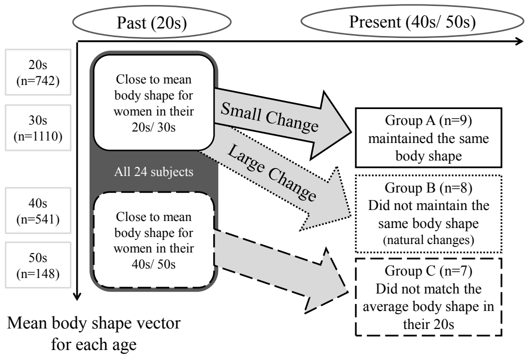

Fig. 2. Body shape changes.

The daily log was a record of how subjects used their time, including any activities that they took part in. Subjects recorded this information in the log throughout the day. Subjects recorded the date and time of the following activities: sleeping, napping, resting, working, housework, moving, exercise, meals, bathing, and periods when the accelerometer was not worn.

A two-tailed t-test was used for independent samples to assess the specific difference between groups.

III. Analytical Method

A. Body shape vector

Body shape was defined as the shape of the subject's silhouette projected onto a vertical plane [4]. Body shape data were collected using a sequence of nodes on the projected silhouette image. The obtained node sequences can be said to describe the body form. In addition, it was shown that an average body shape can be drawn by arithmetically averaging the coordinates of the corresponding nodes among the different silhouette images. In this research, body shape vector, as the horizontal coordinates of 83 node locations that can describe the shape of the trunk (Fig. 1), was used to classify body shape into patterns.

B. Classification of body shape pattern

We previously investigated body shape changes in the same woman over approximately 20 years. In the present study, using a body shape database including women (n=2541) who were born in the 1950s and 1960s, we compared the mean body shape at each age (20s, n=742; 30s, n=1110; 40s, n=541; 50s, n=148) to the individual body shape of each subject over approximately 20 years, and then classified 24 women in their 40s and 50s into 3 groups: A, B, and C (Fig. 2). In Fig. 2, "close to the mean body shape" means that the absolute value of the difference between the mean body shape vector for each age and the individual body shape vector was relatively small. "Small" and "large" changes in body shape were considered to have taken place when the absolute value of the difference between the body shape vector recorded when a subject was in her 20s and that recorded when she was in her 40s was among the 9 smallest values or the 8 largest values, respectively.

Group A comprised women who, when they were in their 20s, had body shapes close to the mean body shape for women in their 20s and 30s, and whose body shape had changed little over the 20 years between their 20s and their 40s (i.e., women who had maintained the same body shape from their 20s through their 40s).

Group B comprised women who, when they were in their 20s, had body shapes close to the mean body shape for women in their 20s and 30s, and whose body shape changed markedly over the 20 years between their 20s and their 40s (i.e., women who had not maintained the same body shape from their 20s through their 40s due to natural changes in weight and fat distribution).

Group C comprised women who, when they were in their 20s, had body shapes close to the mean body shape for women in their 40s and 50s (i.e., women whose body shape did not match the average for their age group when they were in their 20s).

C. Amount of activity

Amount of activity was classified on a time series for weekdays during active periods, sleeping periods, and non-measurement periods (e.g., bathing) using the daily log.

The mean amount of activity during the active period (mean AP) gives an indication of the usual daily activity level during the daytime. Mean AP values are high for subjects with a high level of physical activity and low for those with a low level of physical activity during the daytime. In addition, rates for each level of intensity of the trunk movement during the active period were calculated.

The mean amount of activity during the sleep period (mean SP) gives an indication of sleep quality. Mean SP values are high for subjects with poor sleep quality (i.e., light sleep) and low for those with high sleep quality (i.e., deep sleep). A recent investigation demonstrated that most physical activity during sleep occurs during the shift from deep sleep to light sleep, or during light sleep [5].

Amplitude (AMP) was used to measure the intensity of the sleep-wake cycle. AMP was high for subjects with a high level of physical activity during the daytime and high sleep quality. AMP was calculated as the ratio of mean AP to mean SP.

D. Subjective sleepiness

OSA sleep inventory was used to obtain the subjective sleep score. OSA was compared with the standard score of 50 obtained from data from 670 subjects aged 26 to 75 [3]. Scores higher than 50 were considered to indicate high sleep quality.

TABLE I
FUNDAMENTAL BODY INDICATORS FOR GROUPS A, B, AND C

Indicator	Group	Past (20s)	Present (40s/50s)
Weight (kg)	A	49.2 ± 2.4	48.6 ± 3.3
	B	46.1 ± 4.7	54.9 ± 6.0
	C	63.6 ± 9.5	69.2 ± 9.1
Body mass index (kg/m^2)	A	19.5 ± 1.2	19.3 ± 1.6
	B	19.1 ± 1.4	22.8 ± 2.3
	C	25.2 ± 3.6	27.4 ± 4.2
Waist circumference (cm)	A	62.4 ± 2.4	65.8 ± 2.5
	B	61.1 ± 4.0	76.5 ± 6.5
	C	78.0 ± 10.9	88.5 ± 10.0

TABLE II
HABITS AND LIFE HISTORY FOR GROUPS A, B, AND C

Habits and life history		A %	B %	C %
Diet	Do you eat faster than other people?	22	63	57
	Do you like high-fat foods?	33	50	57
	Do you eat between meals or after dinner more than 3 times a week?	33	38	57
Birth history	Has given birth to one or more children?	67	63	71
Work	Past	100	88	100
	Present	67	63	57
Exercise	Past	89	50	100
	Present	11	25	29
Serious illness	Past	11	0	43

E. Sleep parameters

Sleep parameters including bedtime, time at waking, total sleep time (hours from bedtime on Monday to waking on Friday, including naptime), and total sleep frequency (number of times from bedtime on Monday to waking on Friday, including naptime) were derived from the information recorded in the daily log.

IV. RESULTS

A. Characteristics of groups A, B, and C

The fundamental body indicators measured in advance in the three groups are shown in Table 1. Values are the mean and standard deviation. The habits and life history obtained in advance in the three groups are shown in Table 2. Values are the percentage of the total number of subjects in each group. These data clarify factors associated with body shape change and suggest that diet differed among the groups. Although several women in group C were affected by serious illnesses, their conditions were not chronic.

B. Amount of activity

Fig. 3 shows the amounts of activity of the non-dominant wrist and trunk for 1 subject. Indicators of amounts of activity of the non-dominant wrist and trunk for each group are shown in Fig. 4.

During active periods, the mean amounts of activity were not significantly different among the groups (Fig. 4-a, 4-b). However, between groups A and C, a significant difference ($p<0.05$) was seen in intensity 0 for trunk movement and a marginally significant difference ($p<0.10$) was seen in

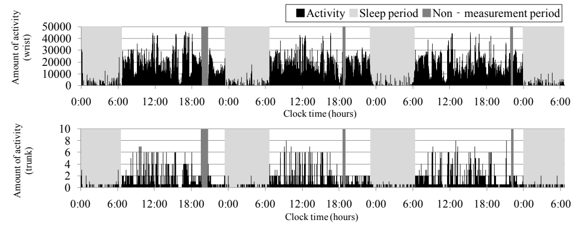

Fig. 3. Amounts of activity of the non-dominant wrist (upper side) and the trunk (under side) for 1 subject.

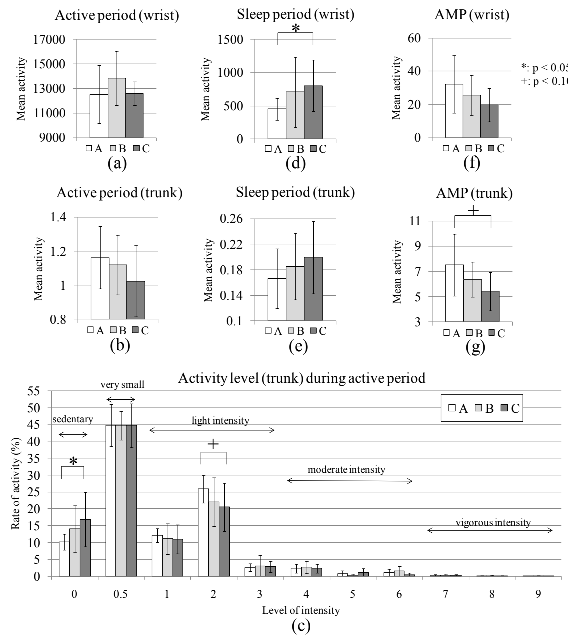

Fig. 4. Indicators of amount of activity for groups A, B, and C.

intensity 2 for trunk movement (Fig. 4-c). Intensity 0 indicates a sedentary activity level, whereas intensity 2 indicates light activity such as walking. Thus, subjects in group A had fewer sedentary periods and more periods of light activity than group C.

During sleep periods, the mean amount of trunk activity was not significantly different among the groups, whereas wrist activity was significantly ($p<0.05$) lower in group A than in group C (Fig. 4-d, 4-e). During sleep periods, the recorded amount of activity suggests that group A had higher sleep quality than group C.

AMP of trunk activity was marginally significantly ($P<0.10$) higher in group A than in group C (Fig. 4-g). This suggests that group A had a higher sleep-wake cycle than groups B and C.

C. Subjective sleepiness

The mean and the standard deviation of subjective sleep score were calculated (Table 3). Regarding the quality of sleep, scores for the second factor of initiation and maintenance of sleep and the fourth factor of recovery from fatigue were higher in group A than in groups B and C. However, the score for the third factor of frequency of dreaming was marginally significantly ($p<0.10$) higher in group B than in group A. Thus, group B slept more lightly

TABLE III
SUBJECTIVE SLEEP AND SLEEP PARAMETERS FOR GROUPS A, B, AND C

Subjective sleep	A	B	C
Factor 1 (sleepiness on rising)	42.65 ± 8.34	40.88 ± 5.04	44.75 ± 11.72
Factor 2 (initiation and maintenance)	48.66 ± 12.55	45.09 ± 8.44	48.11 ± 8.68
Factor 3 (frequency of dreaming)	48.45 ± 11.07	56.37 ± 3.28	51.50 ± 11.07
Factor 4 (recovery from fatigue)	46.36 ± 7.30	42.46 ± 6.83	44.39 ± 10.75
Factor 5 (sleep length)	43.21 ± 5.55	42.76 ± 5.06	42.87 ± 11.54
Sleep parameter	**A**	**B**	**C**
Total sleep time (hours)	25.78 ± 4.23	26.11 ± 5.49	24.90 ± 3.63
Total sleep frequency (number)	5.67 ± 1.94	5.25 ± 1.04	5.43 ± 2.70
Mean bed time (time of day)	0:13 ± 1:01	23:51 ± 1:23	0:14 ± 1:06
Mean waking time (time of day)	6:41 ± 0:37	6:45 ± 0:52	6:50 ± 1:12

than group A.

D. Sleep parameters

The mean and standard deviation of sleep parameters were calculated (Table 3). Total sleep time was 25-26 hours in all groups. Total sleep frequency was 5-6 times in all groups. Mean bedtime ranged from 23:51 to 0:13 in all groups. Mean waking time ranged from 6:40 to 6:50 in all groups. Therefore, all subjects slept for approximately 6.5 hours during each sleep period. There were no significant differences among the groups for these sleep parameters.

V. DISCUSSION

The purpose of this study was to clarify the relationship between circadian rhythm and body shape change. We examined differences in daily life, focusing on circadian rhythms, in women whose body shapes had changed in different ways over 20 years. The results showed that women who had maintained the same body shape showed high rest-activity rhythm. However, distinctive fragmentation of sleep and an advanced (early) sleep-wake schedule were not observed.

The present results are consistent with the findings of previous studies using actigraphy, which found that reducing the amount of time spent on sedentary behavior and increasing the amount of time spent on light physical activity is important in the maintenance of body composition [6]. The present results are not consistent with the results of one previous report, which did not demonstrate any effect for moderate-to-vigorous-intensity exercise [7]. In addition, from the present finding that sleep quality is important, we can discuss changes in circadian rhythm with aging. A study on sleep and rest-activity patterns found that healthy older subjects showed weakened, fragmented circadian sleep and rest-activity rhythms and an advanced (early) sleep-wake schedule with aging, and differences were apparent between subjects within the same age groups [8]. Therefore, there may be a correlation between the maintenance of regular circadian rhythm and the maintenance of body shape during the course of aging. Maintaining circadian rhythms, such as rest-activity and sleep-wake cycle, may be one factor behind the maintenance of body shape with aging.

There are other factors to note. From the present findings regarding habits and life history, birth history, work, exercise, and serious illness do not appear to be significant factors in the maintenance of body shape. This indicates that subjects' circadian rhythm during the experimental period was basically the same as during the previous 20 years. However, in order to clarify the effect of lifestyle on the maintenance of body shape throughout life, it is necessary to continuously record data from a young age. In addition, further research on the evaluation of daily living using several indicators, including amount of activity, using a wearable device would clarify behavior during the active period.

VI. CONCLUSION

The present study investigated an evaluation of daily living focusing on circadian rhythm in subjects who had experienced different body shape changes over 20 years. The results suggest that circadian rhythm—including a less sedentary lifestyle with more trunk movement during the day, sleeping well at night, and having a varied sleep-wake cycle—may be one factor in the maintenance of a constant body shape throughout life.

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