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Seasonal changes in physical activity levels in female university students in Okinawa, Japan

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Abstract

The purpose of this study was to investigate regional differences in seasonal changes in physical activity levels among female university students in Japan's Okinawa and Ibaraki Prefectures.

Participants were 58 female university students in Okinawa and Ibaraki Prefectures. The physical activity levels (total energy expenditure and durations of activities at different intensity levels) were measured using a uniaxial accelerometer on seven consecutive days including a weekend in both summer and winter seasons. Climatic conditions during the survey periods were also recorded. To evaluate seasonal changes in the physical activity levels, repeated measures ANOVA were performed using season (summer or winter) and region (Okinawa or Ibaragi) as independent variables and the physical activity levels as dependent variables.

Repeated measures ANOVA indicated the main of season and region and interaction between them on the total energy expenditure. The total energy expenditure decreased from summer to winter in Okinawa but increased over the same period in Ibaragi. The total energy expenditure in winter was significantly lower in Okinawa than in Ibaragi. As for the duration of light activities, season showed a main effect, and interaction between region and season was observed. The duration of light activities was shorter in winter than in summer in Okinawa. Regarding vigorous activities, a main effect was noted in region, and the duration of vigorous activities was shorter in Okinawa than in Ibaragi.

In conclusion, seasonal changes in the physical activity levels differed between female university students in Okinawa and Ibaragi, and the weather, i.e., rain, is considered to have affected the physical activity levels.

Key word: energy expenditure, weather, accelerometry.

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日本語抄録

本研究の目的は，沖縄県と茨城県の女子大学生における身体活動量の季節変動の地域差について検討することであった。研究参加者は沖縄県と茨城県の女子大学生58名であった。夏季と冬季の２回，一軸加速度計を用いて１週間（週末を含む）の身体活動量（総エネルギー消費量および運動強度別活動時間）の測定を実施した。各季節、各地域における気候条件を記録した。分析は、地域（沖縄・茨城）と季節（夏・冬）を独立変数、身体活動量を従属変数とした繰り返しのある分散分析を行った。繰り返しのある分散分析の結果、総エネルギー消費量については，季節と地域の主効果および季節と地域の交互作用が認められた。沖縄は冬に総エネルギー消費量が減少していたのに対し、茨城は冬に増加していた。また，沖縄の冬の総エネルギー消費量は茨城に比べ低い値を示した。活動時間に関しては、低強度の活動時間に季節の主効果および地域と季節の交互作用が認められた。沖縄では、低強度の活動時間が夏よりも冬に少ないことが示された。さらに、高強度の活動時間については、地域の主効果が認められ、沖縄は茨城に比べて高強度の活動時間が少ないことが示された。結論として，沖縄県と茨城県の女子大学生における身体活動量の季節変動に地域差がみられた。身体活動量の変動には、測定期間の気候条件，すなわち雨が影響していることが考えられた。

Introduction

Determinants of physical activities include many factors of various fields such as demographic, psychological, social, and environmental (Sallis & Owen, 1999; Dishman, et al., 1985), but the relationship between the natural environment, particularly seasonal or climatic factors, and the physical activity level has escaped attention (Tucker & Gilliland, 2007). A few studies on seasonal changes in the physical activity level showed that participation in physical activities is affected by season. For example, Matthews et al., (2001) and Dannenberg et al., (1989) reported that a low ambient temperature hinders participation in physical activities, and that such activities increase during summer, compared with winter. On the other hand, the study of Baranowski et al., (1993) which was conducted in Texas in a subtropical climate, reported decreases in physical activities during hot and humid summer with a mean temperature of 29℃. Tucker & Gilliland (2007) suggested that seasonality and climate show marked regional variation and, thus, exert different effects on participation in physical activities. The accumulation of research results in diverse areas is necessary to perform intervention for the promotion of physical activities suited to local conditions. However, studies on the effect of seasonal changes on the physical activity level have been insufficient in Japan.

Among regions of Japan, Okinawa has a subtropical oceanic climate and is warm throughout the year, with a mean annual temperature of 22-24℃, but the mean temperature during summer is high at 27-29℃, and the annual precipitation is also high at 2,100-2,300 mm (Yamazaki, et al., 1989; Okinawa Meteorologic Observatory, 1996).

These climatic characteristics are considered to have significant effects on the physical activity level among people of Okinawa. While the warmth throughout the year is a factor promoting physical activities, the high temperature during summer may discourage them (Tucker & Gilliland, 2007). It has been reported that people of Okinawa are interested in exercise but have no habit of regular exercise, and their mean daily number of walking steps (7,655 in males, 7,091 in females) is lower than the national average. Moreover, a decline in the state of health in Okinawa, as indicated by the percentage of obese individuals being about 20% higher than the national average, has recently emerged as a public health issue (Okinawa Prefecture, 2008; Okinawa Prefecture, 2003). Therefore, in order to enhance health status and prevent obesity among them, measures to improve the physical activity and exercise habit are strongly required. The investigation of seasonal changes in physical activities in Okinawa Prefecture is expected to lead to the clarification of the effects of climatic factors on physical activities and contribute to the planning of intervention programs to improve the exercise habit in a subtropical climate area. Furthermore, as temperature rises due to global warming have also become a topic in mainland Japan (Japan Meteorological Agency, 2002), the clarification of seasonal changes in the physical activity level in Okinawa, with its high mean temperature, is considered to provide data useful for the preparation of physical activity promotion programs anticipating future temperature elevations.

In this study, regional differences in seasonal changes in the physical activity level were investigated in female university students in Okinawa and Ibaraki Prefectures. It was hypothesized that the physical activity level decreases in summer in Okinawa due to the summer heat and in winter in Ibaragi due to the winter cold. Ibaraki Prefecture, a research field for one of co-researchers, was selected as a reference region. It is located in the Kanto District in mainland Japan, has a mean annual temperature of 13.3℃ and a mean annual precipitation of 1,439 mm (Mito Local Meteorological Observatory, 2008), and is considered to have different geographic and climatic characteristics compared with Okinawa Prefecture.

Subjects and Methods

In this study, to control potential factors that affect the physical activity level other than season, the subjects were limited to female university students. The study sample consisted of 49 second-year students enrolled in the School of Health Sciences at a national university in Okinawa and 35 second-year students of the School Nurse Training Course of the School of Education at a national university in Ibaraki. The second-year students of both universities primarily take lectures concerning their specialties and are not required to participate in special curricula such as clinical practice classes, and thus their lifestyle was not considered to differ markedly as groups.

Prior to the survey, the students were informed orally and in writing that the physical activity level is measured by accelerometry during summer and winter, the survey will be performed by identifying subjects (not anonymously) for follow-up, the data will be statistically processed in a manner that will not cause disadvantages to the subjects, and cooperation in the survey is unrelated to academic records. Consent forms were obtained from 58 students (30 from Okinawa and 28 from Ibaraki), and the data

of 55 (28 from Okinawa and 27 from Ibaraki) after the exclusion of those in whom 1-week data recording was impossible due to disorder of the accelerometer were analyzed. The survey periods were July-August 2007 (summer) and January-February 2008 (winter). The physical activity level was measured on seven consecutive days including a weekend in both periods.

To clarify the basic characteristics of the subjects considered to affect the physical activity level, a questionnaire concerning the housing conditions, state of participation in extracurricular activities, method of going to school, economic conditions, and subjective health status was performed. The height and body weight of the subjects were measured, and the body mass index (BMI) was calculated.

The physical activity level (total energy expenditure and durations of activities at different intensity levels) was measured by using a uniaxial accelerometer (Lifecorder; Suzuken Co., Ltd.). The subjects were instructed to wear an accelerometer on a belt except during sleep and taking a bath and to maintain ordinary lifestyle habits during the survey. The uniaxial accelerometer used in this study sensed physical activities according to vertical movements caused by locomotion and their frequency, classified them into the 11 intensity levels of zero for resting, 0.5 for minor movements, and 1-9, and recorded them every 4 seconds (Kumahara, et al., 2004; Higuchi, et al., 2003). It also automatically calculated the basal metabolic rate on inputting the gender, age, height, and body weight of the subject (Kumahara, et al., 2004). The total energy expenditure was calculated by the accelerometer as a sum of the basal metabolic rate, physical-activity-related energy expenditure, energy expenditure by minor physical activities, and diet-induced thermogenesis (DIT), which was estimated to be 10% of the total energy expenditure (Kumahara, et al., 2004). Since the subjects were female university students with a sedentary lifestyle, minor activities during desk work, taking a bus or driving a car, watching TV, etc., were expected to be observed over a long duration. Therefore, the total energy expenditure including energy expenditure due to minor physical activities was used as an index, and its daily mean was calculated.

In addition, to calculate the time spent engaged in physical activities, intensity levels 1-3, 4-6, and 7-9 were categorized as light, moderate, and vigorous activities, respectively, and mean daily durations of activities in these categories were calculated. Previous studies have confirmed that light, moderate, and vigorous activities approximately correspond to <3METs, 3-6 METs, and ≥6METs, respectively (Kumahara, et al., 2004).

To clarify climatic conditions during the survey periods, the data concerning the temperature, humidity, precipitation, and hours of sunlight made public by the Meteorological Agency in each season and region were recorded (Japan Meteorological Agency, 2008).

For analysis, the χ^2-test was performed first to evaluate the relationships between the basic characteristics of the subjects and the region. Next, the t-test and analysis of variance (ANOVA) were performed to examine the differences in the physical activity level according to basic characteristics. Finally, to evaluate seasonal changes in the physical activity level, repeated measures ANOVA were performed using season (summer or winter) and region (Okinawa or Ibaraki) as independent variables and the total energy expenditure and mean durations

of light, moderate, and vigorous physical activities as dependent variables. Since a regional difference was observed in the methods of going to school, it was adjusted as a covariate. Regarding climatic conditions (temperature, precipitation, and humidity), the basic statistics of each region were calculated for summer and winter, and regional differences were examined using Mann-Whitney's U-test. A criterion of $p < 0.05$ for statistical significance was applied.

Results

Table 1 shows the basic characteristics of the subjects in each region. A significant regional difference was noted in the methods of going to school. The percentage of those who went to school by means other than walking or bicycle was higher in Okinawa than in Ibaraki. Table 2 reveals climatic conditions in each season and region during the survey periods. The temperature was higher in Okinawa in both summer and winter. The precipitation showed a significant regional difference in winter and was higher in Okinawa. The humidity showed a significant regional difference in summer and was higher in Ibaraki. The hours of sunlight showed significant regional differences in both seasons; they were longer in summer for Okinawa but in winter for Ibaraki. Table 3 demonstrates the mean total energy expenditures according to basic characteristics in different seasons. It did not differ significantly according to basic characteristics in summer or winter. Table 4 shows the mean total energy expenditure in each region in

Table 1. The basic characteristics of the subjects in each region.

		Okinawa		Ibaraki			
		n	%	n	%	χ^2	p
Housing conditions[a]	With family	18	64.3	11	40.7		0.108
	Others	10	35.7	16	59.3		
Extracurricular activities[a]	Participating	6	21.4	8	29.6		0.547
	Not	22	78.6	19	70.4		
Methods of going to school[a]	Walking or Bicycle	2	7.1	15	55.6		<0.001
	Others	26	92.9	12	44.4		
Economic conditions	High	2	7.1	1	3.7	0.906	0.636
	Moderate	23	82.1	21	77.8		
	Low	3	10.7	5	18.5		
Health status	Very healthy	4	14.3	3	11.1	0.292	0.864
	Quite healthy	21	75.0	20	74.1		
	Not very healthy	3	10.7	4	14.8		
		Mean	SD	Mean	SD	t	p
Age		19.8	0.8	19.6	0.7	0.754	0.454
Height (cm)		157.2	4.4	157.4	5.6	-0.171	0.865
Weight (kg)		49.3	5.7	51.2	6.6	-1.103	0.275
BMI (kg/m^2)		19.9	2.0	20.6	1.9	-1.225	0.226

[a]Fisher's exact test.

Table 2. Climatic conditions in each season and region during the survey periods.

		Okinawa			Ibaraki				
		Mean	S.D	Me[a]	Mean	S.D	Me[a]	z[b]	p
Temperature(℃)	Summer	29.8	0.3	29.8	21.3	0.7	21.5	-3.373	<0.001
	Winter	17.0	1.0	16.6	5.4	1.4	5.1	-3.366	<0.001
Precipitation(mm)	Summer	0.0	0.0	0.0	2.4	6.5	0.0	-1.461	0.442
	Winter	3.4	4.8	1.0	0.0	0.0	0.0	-2.098	<0.001
Humidity(%)	Summer	76.4	1.8	77.0	81.6	4.5	81.5	-2.551	0.010
	Winter	74.1	10.7	74.0	73.9	5.8	73.5	-0.263	0.798
Sunlignt(hour)	Summer	11.0	1.3	10.7	4.7	2.8	5.7	-3.363	<0.001
	Winter	0.2	0.5	0.0	4.6	3.4	5.4	-2.850	0.005

[a]: Median.
[b]: Mann-Whitney U test.

Table 3. The means of total energy expenditures according to basic characteristics in different seasons.

			Summer		t/F	p	Winter		t/F	p
		n	Mean	SD			Mean	SD		
Housing conditions	With family	26	1557.2	95.8	1.39	0.170	1550.4	116.0	0.749	0.457
	Others	29	1601.4	138.2			1581.6	188.5		
Extracurricular activities	Participating	14	1570.8	145.7	0.262	0.795	1585.1	231.4	-0.559	0.579
	Not	41	1580.5	110.0			1558.3	119.8		
Methods of going to school	Walking or Bicycle	17	1610.1	133.6	1.347	0.184	1591.8	119.8	0.859	0.394
	Others	38	1563.8	110.3			1553.2	166.9		
Economic conditions	High	3	1592.3	25.8	0.700	0.501	1508.9	21.1	0.248	0.781
	Moderate	44	1585.5	129.0			1565.7	167.6		
	Low	8	1532.1	61.9			1583.0	90.1		
Health status	Very healthy	7	1677.8	165.6	3.757	0.050	1649.3	284.8	1.901	0.160
	Quite healthy	41	1555.9	102.1			1542.5	122.3		
	Not very healthy	7	1608.3	118.7			1613.6	133.1		

Table 4. The means of total energy expenditure in each region in different seasons.

	Okinawa				Ibaraki				Main effect					
	Summer		Winter		Summer		Winter		Region		Season		Interaction	
	Mean[a]	SE	Mean[a]	SE	Mean[a]	SE	Mean[a]	SE	F	p	F	p	F	p
Total energy expenditure (Kcal/day)	1559.6	24.2	1465.6	24.2	1597.2	24.8	1668.4	26.9	10.805	0.002	13.387	0.001	38.450	<0.001

[a]Adjusted for methods of going to school.

Table 5. The means of duration of activities at different intensity levels in each region in different seasons.

	Okinawa				Ibaraki				Main effect					
	Summer		Winter		Summer		Winter		Region		Season		Interaction	
	Mean[a]	SE	Mean[a]	SE	Mean[a]	SE	Mean[a]	SE	F	p	F	p	F	p
Light (min/day)	48.6	2.8	36.2	2.3	42.5	2.8	41.0	2.3	0.036	0.850	4.977	0.030	5.863	0.019
Moderate (min/day)	18.3	1.4	15.5	1.4	20.8	1.4	19.8	1.4	3.844	0.055	1.694	0.199	0.565	0.456
Vigorous (min/day)	1.9	0.3	1.5	0.7	2.5	0.3	4.0	0.7	5.912	0.019	1.475	0.230	4.043	0.050

[a]Adjusted for methods of going to school.

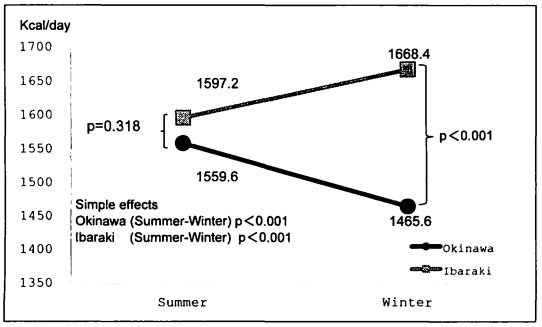

Figure 1. The means of total energy expenditure in each region in different season.

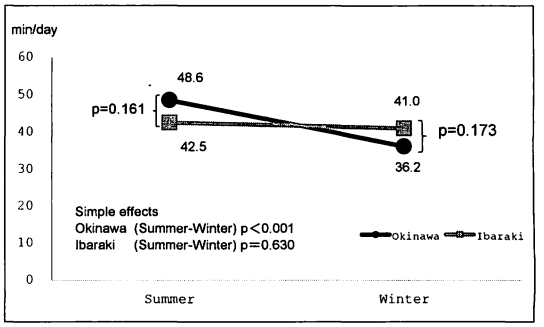

Figure 2. The means of duration of light activity intensity in each region in different season.

different seasons. Repeated measures ANOVA indicated the main effects that season and region had and the interaction between them. The test of the simple main effect indicated that the total energy expenditure decreased significantly from summer to winter in Okinawa but increased significantly over the same period in Ibaraki. The total energy expenditure in winter was significantly lower in Okinawa than in Ibaragi (Figure 1). Table 5 presents the mean durations of activities in different intensity categories for each region in different seasons. Concerning the duration of light activities, season showed to have a main effect, and a direct correlation between the region and season was observed. The test of the simple main effect indicated that the duration of light activities was shorter in winter than in summer in Okinawa (Figure 2). Concerning the duration of moderate activities, no main effect was noted to correlate with in region or season. Regarding vigorous activities, a main effect was noted to correlate with region, and the duration of vigorous activities was shorter in Okinawa than in Ibaraki.

Discussion

In this study, seasonal changes in the physical activity level were evaluated in female university students in Okinawa and Ibaraki. Prefectures. While the total energy expenditure decreased from summer to winter in the Okinawa group, it increased over the same period in the Ibaraki. group. Okinawa has a subtropical oceanic climate and is characterized by a high temperature and sunny days in summer but cloudy days with occasional showers in winter (Yamazaki, et al., 1989; Okinawa

Meteorologic Observatory, 1996). In Ibaraki., on the other hand, there are many rainy days in summer due to seasonal wind from the Pacific Ocean; but winter is dry and sunny because seasonal wind from the Japan Sea is blocked by mountains (Yoshino, 2004). During the survey periods of this study, the temperature was higher in Okinawa than in Ibaraki in both seasons, and there were more rainy days in winter in Okinawa but more in summer in Ibaraki thus the weather in the survey periods reflected the climates of the respective regions. Many studies on seasonal changes in the physical activity level reported decreases in the physical activity level from summer to winter (Matthews, et al., 2001; Dannenberg, et al., 1989), but a survey conducted in a subtropical region indicated a decrease in the physical activity level in summer (Baranowski, et al., 1993). Therefore, in this study, we hypothesized that the physical activity level would decrease in summer in Okinawa and in winter in Ibaraki, similarly to previous studies, but the results were opposite to the hypothesis. The reason why the seasonal changes in the physical activity level in this study differed from the hypothesis is probably because of the weather during the survey periods. As mentioned above, there were more rainy days in winter in Okinawa but in summer in Ibaraki with associated significant regional differences in the hours of sunlight in both seasons, being longer in summer in Okinawa but in winter in Ibaraki. Previous studies suggested that climatic conditions may promote or inhibit physical activities and that the hours of sunlight, temperature, and precipitation affect outdoor activities such as walking (Haggarty, et al., 1994; Plasqui & Westerterp, 2004; Currie & Develin, 2002; Yusuf, et al., 1996). For example, Plasqui & Westerterp (2004) who measured the physical activity level by the doubly labeled water method, showed that the physical activity level decreased from summer to winter and suggested a decrease in the duration of outdoor activities during winter due to less hours of sunlight and adverse weather such as rain. Decreases in the physical activity level were also observed in this study during periods of bad weather, so that precipitation and less hours of sunlight are considered to have inhibited physical activities.

Furthermore, Plasqui & Westerterp (2004) suggested that a decrease in the duration of non-exercise activity thermogenesis might explain the decrease in the activity level in winter. Non-exercise activity thermogenesis is due to activities of mostly light to moderate intensity including the maintenance of posture (sitting, standing, etc.), housework such as cleaning and washing, shopping, walking for commuting to work, leisure activities such as gardening, and carrying things during work (Levine, 2007; Tanaka, 2006). Such activities may be particularly hindered by rain (Plasqui & Westerterp, 2004). In this study, the duration of light activities decreased in Okinawa in winter, when there was much precipitation. This supports the findings of Plasqui & Westerterp (2004) and suggests that bad weather inhibits not only exercise but also low-intensity physical activities. It has recently been reported that increasing the energy expenditure by not only sports but also routine physical activities is effective in the prevention of diseases and promotion of health (Haskell, et al., 2007; Saris, et al., 2003). Thus, it is extremely important to maintain a routine activity level even in bad weather.

The duration of vigorous activities was short in the Okinawa group. Vigorous activities are activities at 6 METs or higher and include jogging, going up and down stairs,

and carrying heavy luggage (Ainsworth, et al., 2000), and such high-intensity activities were rarely performed by female university students in Okinawa. According to the health and nutrition survey in Okinawa Prefecture in 2006 (Okinawa Prefecture, 2006), 70% of young people made no effort to exercise for the promotion of health, and only 5% or less performed high-intensity exercise, suggesting that they have few chances to exercise other than through activities of daily living. Since the lifestyle of female university students is characteristically sedentary, they may have even fewer chances to exercise than the average population. Arai et al., (2005) reported that the routine activity level decreases when young people enter university due to causes such as a decrease in the necessity to maintain regularity in daily life. Since habits related to the occurrence of lifestyle-related diseases in middle age are formed and established in university years, this period is important for the early prevention of lifestyle-related diseases. Particularly, the percentage of females in Okinawa who do not exercise increases further after the late 20's, and the percentage of obese individuals exceeds the national average in the 30's, (Okinawa Prefecture, 2008). Therefore, the acquisition and maintenance of regular exercise habits are important for the prevention of lifestyle-related diseases including obesity in Okinawa Prefecture.

A limitation of this study was the method for the measurement of the physical activity level. While the uniaxial accelerometer used in this study has been adopted in various studies for the objective evaluation of the physical activity level, studies on the relationship between accelerometry and the doubly labeled water method have suggested that the activity level tends to be underestimated by accelerometry (Kumahara, et al., 2004; Higuchi, et al., 2003). Moreover, Harada et al., (2001) reported that the daily total energy expenditure was significantly underestimated by accelerometry using Lifecorder compared with the heart rate method. Uniaxial accelerometry does not reflect activities primarily of the upper body, those performed in situations in which the accelerometer cannot be worn such as swimming, and those that cannot be sensed with the accelerometer such as cycling and going up and down stairs. In addition, the energy expenditure or activity level indicated by the uniaxial accelerometer comprises values estimated from the body weight and age rather than those obtained by actual measurements (Katayama, et al., 2008). Therefore, there is the possibility that the total energy expenditure was underestimated in this study. Moreover, the number of subjects was small, and they were limited to female university students in Okinawa and Ibaraki, and so the results may only be applicable to particular regions and population groups.

In conclusion, seasonal changes in the physical activity level differed between female university students in Okinawa and Ibaraki, and the weather, i.e. rain, is considered to have affected the physical activity level. However, as the direct relationships between climatic conditions and the physical activity level could not be evaluated in this study, they require further evaluation. The findings suggest that the physical activity level is affected by regional climatic characteristics and indicate the importance of the investigation of seasonal changes in the physical activity level in a wide variety of regions in order to develop physical activity promotion programs more appropriate for regional characteristics.

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