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Negative energy balance of Japanese university students during COVID-19 epidemic

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Abstract

The early identification of the energy balance may help to identify an individual's diet and physical activity. To investigate the state of energy balance among male and female university students in Japan during the COVID-19 epidemic, self-reported three-day food and activity records were collected from 457 university students aged 18–24 years. The energy intake variables included the calorie intake, number of meals, and calories per meal. Energy expenditure was calculated as a sum of resting energy expenditure and physical energy expenditure. Information on academic major and living status were obtained. This study showed that both males and females had a negative energy balance, which was caused by an insufficient energy intake. High levels of physical activity aggravated the negative energy balance. Efforts should be made to promote healthful and appropriate dietary patterns in young adults especially in individuals with higher physical activity levels. Subjects who were living alone showed significantly decreased total energy intake and total energy expenditure, although no significant difference was observed for energy balance. Attention should be paid to the possible insufficient energy intake and level of exercise in young adults who are living alone.

Key Words: COVID-19, energy balance, Japanese young adults, energy intake, physical activity level, living alone
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Introduction

Energy stores are determined by the energy balance, which refers to a complex interaction between energy intake and energy expenditure. When the energy intake is equal to the energy expenditure over time, the body weight tends to be stable ¹⁾, and body weight can be adjusted by establishing a positive or negative energy balance. The body mass index (BMI, the body weight in kilograms divided by height in meters squared [kg/m^2]) is a simple index of weight-for-height that is widely used to classify the body weight of adults into the following categories: underweight ($<18.5 \text{ kg}/\text{m}^2$), normal weight ($18.5\text{-}24.9 \text{ kg}/\text{m}^2$), overweight ($25.0\text{-}29.9 \text{ kg}/\text{m}^2$), and obese ($>30 \text{ kg}/\text{m}^2$).

Education can influence health behavior and some studies have emphasized the importance of developing knowledge on the energy balance through education for enabling behaviors associated with weight management ²⁾. We predicted that the energy balance variables would differ between liberal arts and science students due to probable differences in health knowledge and lifestyles.

The association of the living status with the nutrient intake and exercise is unclear. A survey among Korean adults reported that people living alone appeared to have a lower health status and poorer quality diet ³⁾. During the COVID-19 epidemic, living alone might aggravate meal irregularity, decreasing physical activity and other lifestyle factors.

According to the latest Japanese National Health and Nutrition Survey 2018, 20% of Japanese individuals of 15-29 years of age were underweight (BMI $<18.5 \text{ kg}/\text{m}^2$); this rate is higher in comparison to other age groups. A number of studies in Japan have reported the prevalence of underweight young women ^{4, 5)} and negative energy balance among female students ^{6, 7)}, however, there is little information about the energy balance among young men.

Due to the COVID-19 pandemic, schools have moved online, and students are no longer attending school. It is necessary to examine their energy balance during the pandemic. In this study, we aimed to investigate the state of energy balance among male and female university students by comparing the energy intake and energy expenditure of each participant. We

also wanted to determine the predictive power of the energy balance in order to provide personalized advice for different groups of people.

Methods

Procedures

In July 2020, as physical education assignments, self-reported three-day food and activity records which were required in this study had been finished by all the first-year students at Q University in Japan. In August 2020, a document describing the outline of this research and a consent form was distributed at the same time by email to all the potential participants. Only data from subjects who provided informed consent would be used.

Participants

The respondents included 457 first-year students (average age 18.6 ± 0.78) enrolled at Q University in Japan. This was a non-randomized study due to the subjects' educational level and school. Written informed consent was obtained from all participants.

Survey content

Subject characteristics

Demographic data, including age, sex, academic major, height, weight, living status and BMI, were computed.

Dietary records

In a 3-day dietary record (two consecutive weekdays and one weekend day), all the food and beverages consumed, with details of the food type, amount, calorie content and time of day was recorded. The calorie content of foods was estimated by referring to a database (DietQ²U: Diet Questionnaire of Q University) created by the Health and Sports Science Study Group of this school. In cases in which the consumed food was not available in this database, other databases (e.g., “calorie Slism” <https://calorie.slism.jp/>) were also used for the analysis of dietary intake or the participant directly referred to the food composition table. Survey recording forms with the instruments were sent by email. All dietary records were checked for accuracy and completeness by researchers. The average values of the energy intake variables for the three days (calorie intake [kcal/day], number of meals [n/day], calories per meal [kcal]) were statistically analyzed.

Table 1. Descriptive statistics for demographic variables, energy intake variables and energy expenditure variables.

	Male	Female	Sig.
Demographic variables			
N	269	188	-
Age	18.7±0.82	18.6±0.70	0.123
Weight (kg)	61.7±8.20	49.1±5.30	0.000
Height (cm)	170.7±5.63	157.8±5.21	0.000
BMI (kg/m ²)	21.2±2.46	19.7±1.94	0.000
Living alone	97(36.06%)	58(30.85%)	0.262
Academic major (science)	175(65.06%)	92(48.94%)	0.000
Energy intake variables			
Calorie intake (kcal/day)	1981.1±405.52	1627.0±315.04	0.000
Calorie intake (kcal/kg/day)	32.5±7.30	33.5±7.38	0.165
Number of meals (n/day)	3.6±0.79	3.8±0.67	0.015
Calorie per meal (kcal)	562.5±136.33	438.0±98.83	0.000
Calorie per meal (kcal/kg)	9.2±2.27	9.0±2.28	0.404
Energy expenditure variables			
Total energy expenditure (kcal/day)	2689.7±421.47	2171.6±264.10	0.000
Total energy expenditure (kcal/kg/day)	43.8±5.93	44.5±5.66	0.228
Basal metabolic rate (kcal/day)	1536.4±111.58	1220.7±76.47	0.000
Basal metabolic rate (kcal/kg/day)	25.1±1.64	25.0±1.41	0.535
Sedentary time (h)	9.4±2.51	8.6±2.14	0.001
Sleeping time (h)	8.3±1.18	8.0±0.95	0.002
Physical activity level	1.8±0.23	1.8±0.19	0.120
Energy balance (kcal/day)	-708.6±540.65	-544.7±403.65	0.000
Energy balance (kcal/kg/day)	-11.3±8.13	-11.0±8.34	0.695

Physical activity records

Participants were also asked to record physical activities simultaneously using the dietary record. This 3-day activity record has been shown to be a suitable procedure for estimating energy expenditure⁸⁾ and has been used as a highly valid method for surveying physical activity in Japan. This record contains data about the time of day, types of physical activity, relative metabolic rate, and duration of activity.

The relative metabolic rate (RMR), which was originally developed and used in Japan⁹⁾, provides an estimate of the activity intensity using the following formula: $RMR = \text{Active Metabolic Rate} / \text{Basal Metabolic Rate}$. The RMR is provided for some common activities. Sedentary behavior is any waking behavior characterized by an energy expenditure of

≤ 1.5 metabolic equivalents (METs) and $RMR = 1.2 \times (\text{METs} - 1)$. In the present study, we calculated the sum of the duration of activities with an $RMR \leq 0.6$ as the sedentary time (in hours).

The basal metabolic rate (BMR) in kcal/h was calculated based on an age and sex-specific basal metabolism standard and weight¹⁰⁾. The sum of the duration of activities was calculated and used in the energy expenditure calculations. The equations used to determine the resting energy expenditure (REE) and physical energy expenditure (PAEE) were as follows: $REE = BMR [kcal/h] \times (1.25 \times (24 - \text{sleeping time [h]}) + 0.95 \times \text{sleeping time [h]})$, $PAEE = BMR [kcal/h] \times \sum (RMR \times \text{duration [h]})$ ⁹⁾. Total energy expenditure (TEE) was calculated as the sum of REE and PAEE. The physical activity level (PAL) was expressed as the ratio of TEE/BMR and was divided into three levels:

light activity (1.40-1.60), moderate activity level (1.60-1.90), and severe activity level (1.90-2.20)¹⁰. The average calorie intake and average energy expenditure were compared to determine the energy balance.

Statistical analyses

All data were expressed as n (%) or the mean $\pm$ SD. A t -test was used to analyze the difference between males and females. Multiple linear regression was used to identify determinants of the energy balance, energy intake and energy expenditure. Sex, age, BMI, academic major, living alone, number of meals, calories per meal and PAL were included in the models as variables of characteristics, energy intake and energy expenditure. Sex, academic major and

living alone were binary variables, and were recoded as follows: male, 0; female, 1; liberal arts, 0; science, 1; and living alone, 0; not living alone, 1. All analyses were performed using SPSS (Version 25). P values of <0.05 were considered to indicate statistical significance.

Results

Descriptive statistics, energy intake variables and expenditure variables estimate for the 457 subjects are shown in Table 1. Figure 1 shows the distribution of the energy intake (A) and energy expenditure (B). The average age of the male and female students was 18.69 ± 0.82 and 18.57 ± 0.70 years, respectively.

Significant differences between males and females

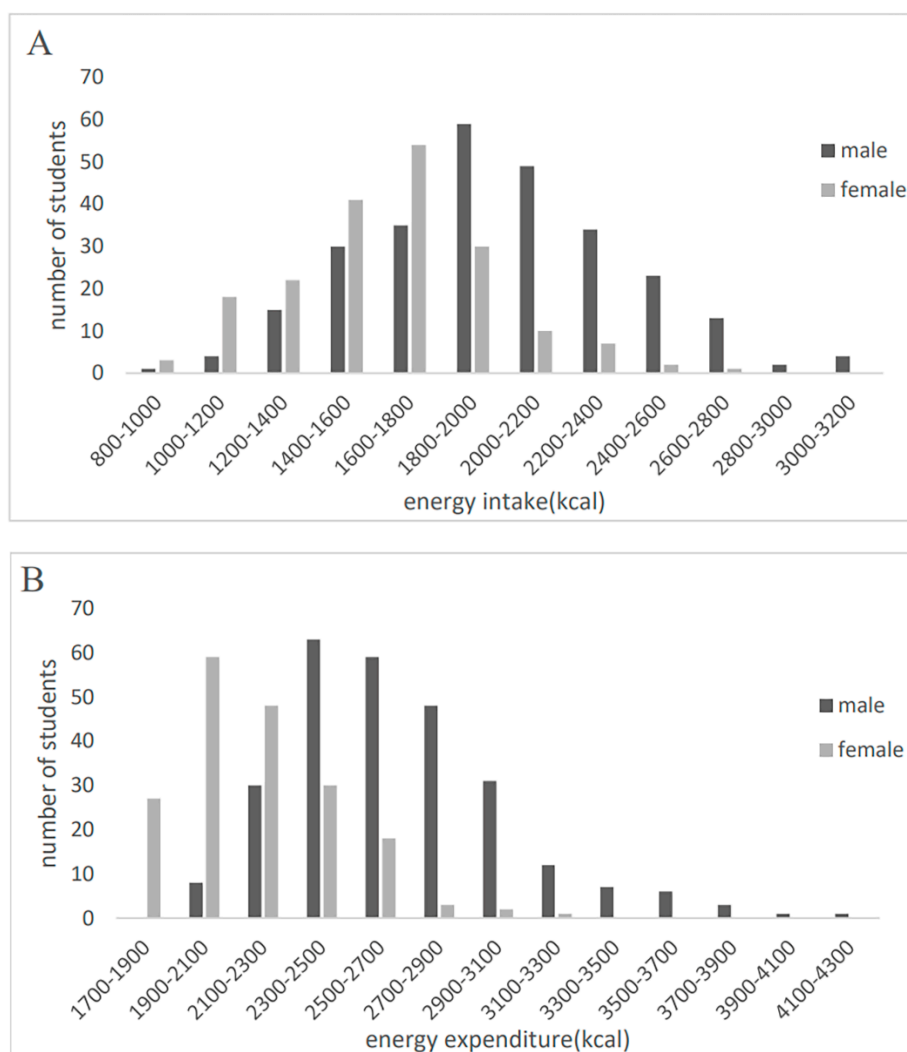


Figure 1. Distribution of the energy intake(A) and energy expenditure(B) of male and female university students.

were observed for weight, height, BMI, and academic major. The differences in living status and PAL were not statistically significant. Similarly, significant differences between males and females were observed for calorie intake (kcal/day), number of meals (n/day), calories per meal (kcal), TEE (kcal/day), BMR (kcal/day), energy balance (kcal/day); however, no significant differences were observed for calorie intake (kcal/kg/day), calories per meal (kcal/kg), TEE (kcal/kg/day), BMR (kcal/kg/day), or energy balance (kcal/kg/day). Females also spent less time in both sedentary and sleeping states in comparison to males.

A multiple linear regression analysis was performed to examine the predictors of energy balance (Table 2). Eight predictors were included in the model at the same time; together, these predictors explained the 85.6% variance in energy balance ($P = 0.000$). With the exception of age, academic major and living alone, all variables were significant predictors of energy balance. Number of meals ($\beta = 0.68$) and calories per meal ($\beta = 0.85$) were positively related to energy balance. The energy balance of the female subjects was significantly higher than that of the males subjects ($\beta = 0.45$). PAL ($\beta = -0.61$) and BMI ($\beta = -0.24$) were negatively related to the energy balance.

The same model was applied to examine the

predictors of the total calorie intake (kcal/day) (A) and calorie intake (kcal/kg/day) (B) with adjustment for body weight (Table 3). All the predictors together explained the 91.7% variance in total calorie intake (kcal/day) ($P = 0.000$) and 79.8% variance in calorie intake (kcal/kg/day) ($P = 0.000$). Calories per meal, number of meals, sex, and age were significant predictors of the total calorie intake (kcal/day) and calorie intake (kcal/kg/day). However, living alone and PAL were just significant predictors of the total calorie intake (kcal/day) and BMI was just significant predictor of the calorie intake (kcal/kg/day).

We also examined the predictors of total energy expenditure (kcal/day) (A) and energy expenditure (kcal/kg/day) (B) with adjustment for body weight, using the same multiple linear regression model (Table 4). All of the predictors together explained the 90.4% variance of total energy expenditure (kcal/day) ($P = 0.000$) and 97.6% variance of calorie intake (kcal/kg/day) ($P = 0.000$). With the exception of academic major, living alone and energy intake variables, all variables were significant predictors of both total energy expenditure (kcal/day) and energy expenditure (kcal/kg/day). Living alone was just significant predictor of total energy expenditure (kcal/day) ($P = 0.019$).

Table 2. Multiple linear regression model for explaining the variations in energy balance.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-810.04	245.13		-3.30	0.001
Sex	452.87	21.38	0.45	21.18	0.000
Age	12.54	11.69	0.02	1.07	0.284
BMI	-49.67	4.06	-0.24	-12.24	0.000
Academic major	23.61	18.53	0.02	1.27	0.203
Living alone	-6.86	19.00	-0.01	-0.36	0.718
Number of meals	446.85	14.37	0.68	31.11	0.000
Calorie per meal	3.10	0.09	0.85	34.59	0.000
Physical activity level	-1403.86	42.41	-0.61	-33.10	0.000

Table 3. Multiple linear regression model for explaining the variations in energy intake.

Model	Total Calorie intake (kcal/day)				
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-1089.58	153.84		-7.08	0.000
Sex	-39.34	13.42	-0.05	-2.93	0.004
Age	-28.00	7.33	-0.05	-3.82	0.000
BMI	1.24	2.55	0.01	0.49	0.627
Academic major	5.82	11.63	0.01	0.50	0.617
Living alone	26.14	11.92	0.03	2.19	0.029
Number of meals	460.29	9.02	0.84	51.06	0.000
Calorie per meal	3.17	0.06	1.06	56.40	0.000
Physical activity level	54.43	26.62	0.03	2.05	0.041

Model	Calorie intake (kcal/kg/day)				
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	12.76	4.30		2.97	0.003
Sex	4.34	0.38	0.29	11.58	0.000
Age	-0.57	0.21	-0.06	-2.76	0.006
BMI	-1.47	0.07	-0.48	-20.68	0.000
Academic major	0.13	0.33	0.01	0.39	0.693
Living alone	0.14	0.33	0.01	0.41	0.679
Number of meals	7.80	0.25	0.80	30.97	0.000
Calorie per meal	0.06	0.00	1.03	35.14	0.000
Physical activity level	1.13	0.74	0.03	1.52	0.129

Discussion

Based on the three-day dietary and physical activity records, both male and female students were found to be in a state of negative energy balance. This finding is in agreement with other studies reporting that Japanese female students had a negative energy balance (-473 ± 460 kcal)⁷⁾, and the negative energy balance during this epidemic seems to be more serious. In our study, both males (-708.6 ± 540.65 kcal) and females (-544.7 ± 403.65 kcal) had a negative energy balance, which indicated they would lose 0.64 kg and 0.49 kg per week respectively if they continued this trend. The weight loss response to the negative energy change is slow and not a linear relationship, the

accurate prediction of body weight accounts for a dynamic energy imbalance¹¹⁾; however, the early identification of the energy balance may help to identify an individual's diet and physical activity. In addition, this study reported on the association of the energy balance with some key variables in the characteristics, energy intake, and energy expenditure.

Demographic variables and the energy balance

A sex difference was found in energy balance, and sex had significant associations with both the energy intake and energy expenditure. Males tended to have a higher total energy expenditure and resting energy expenditure. Because males have more skeletal

muscle and weight in comparison to females, the higher energy expenditure can be at least partly explained by body composition differences¹²⁾. At the same time, males tended to have a higher energy intake. However, the sex difference was found in neither the energy intake per body weight nor energy expenditure per body weight. This indicated that it may be the body weight that make the sex difference in energy balance obvious and other variables, such as less sedentary time and sleeping time in females could partly modulate the low energy expenditure caused by their body composition.

Both energy intake and energy expenditure were negatively correlated with age, and no age difference was found in energy balance. A physiological decline

in the energy intake at 20-80 years of age has been demonstrated in large populations¹³⁾. This study showed the same result, although the average age of our participants was <20 years, which indicated that the age-related physiological decline might happen earlier. The basal metabolic rate declines with aging¹²⁾, which is inadequate to prevent obesity in many middle-aged individuals¹⁴⁾. However, this study showed no age difference in the energy balance, which suggested that the lower energy expenditure due to aging can be compensated by reduced energy intake at the same time in young individuals.

In the present study, academic major did not show a significant association with energy intake, energy expenditure, or energy balance. This might indicate

Table 4. Multiple linear regression model for explaining the variations in energy expenditure.

A					
Total energy expenditure (kcal/day)					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-279.54	180.21		-1.55	0.122
Sex	-492.21	15.72	-0.54	-31.31	0.000
Age	-40.54	8.59	-0.07	-4.72	0.000
BMI	50.91	2.98	0.27	17.07	0.000
Academic major	-17.79	13.62	-0.02	-1.31	0.192
Living alone	33.00	13.96	0.04	2.36	0.019
Number of meals	13.45	10.56	0.02	1.27	0.204
Calorie per meal	0.07	0.07	0.02	1.10	0.273
Physical activity level	1458.29	31.18	0.70	46.77	0.000

B					
Energy expenditure (kcal/kg/day)					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	40.64	1.17		34.71	0.000
Sex	-1.77	0.10	-0.15	-17.36	0.000
Age	-0.88	0.06	-0.12	-15.76	0.000
BMI	-1.13	0.02	-0.46	-58.53	0.000
Academic major	0.05	0.09	0.00	0.51	0.613
Living alone	-0.14	0.09	-0.01	-1.53	0.126
Number of meals	-0.05	0.07	-0.01	-0.77	0.441
Calorie per meal	0.00	0.00	0.01	1.09	0.278
Physical activity level	24.95	0.20	0.92	123.15	0.000

that there was no obvious difference in the knowledge on energy balance between liberal arts students and science students and that as a consequence, there was no difference in diet or activity habits. Alternatively, it might indicate a gap between knowledge and action, as another study showed that accurate knowledge did not guarantee a change in food choices¹⁵⁾. The improvement of knowledge is essential; however, methods for stimulating decision-making should be considered.

An association between living alone and poor health outcomes has been reported; however, few conclusions can be drawn about energy intake¹⁶⁾. The present study demonstrated that in comparison to subjects who were living with parents or roommates, subjects who were living alone showed significantly decreased total energy intake and total energy expenditure. Attention should be paid to the possible insufficient energy intake and level of exercise in young adults who are living alone. However, after adjustment for weight, living alone did not show a significant association with energy intake or expenditure. This suggested that body weight or body weight-related factors might make the connection between living alone and energy intake and expenditure indeterminate.

BMI has been shown to be negatively correlated with activity energy expenditure per body weight¹⁷⁾ and resting energy expenditure per body weight¹⁸⁾, which was in accordance with our results. In our study, BMI was negatively related to the total energy expenditure per body weight. This indicated that lean people might have performed higher intensity physical activities or have more lean-body-mass composition per body weight. BMI was found to be positively correlated with total energy expenditure, which might be due to body weight changes; thus, body weight might be superior to BMI as a predictor of total energy expenditure, as shown in another study¹⁹⁾. At the same time, BMI showed no significant correlation with total energy intake, which suggested that negative energy balance was caused by higher energy expenditure with insufficient energy intake. Furthermore, BMI was negatively correlated with

energy intake per body weight, which might be related to changes in energy expenditure per body weight; this will be discussed later.

Energy intake/expenditure variables and energy balance

The number of meals and calories per meal was positively correlated with energy intake and energy balance, and PAL was positively correlated with energy expenditure and negatively correlated with energy balance; it is unlikely that someone with a higher calorie intake or lower intensity physical activities would be in a state of negative energy balance.

Under the influence of exercise type, intensity, or duration, along with subject characteristics, there is a lack of evidence on the acute effects of energy expenditure on energy intake²⁰⁾. Once higher physical activity is performed regularly, within a certain zone (“normal activity”), the calorie intake increases with activity to maintain the energy balance²¹⁾. In our study, the PAL was positively correlated with the total energy intake, while there was no significant association between the PAL and the total energy intake per body weight, which suggested that adjustment for the calorie intake removed the confounding effect of body size and might better reflect the energy intake. The energy expenditure per body weight increased with higher physical activity; however, this was not compensated by an increase in energy intake per body weight. This indicated that individuals with a higher PAL could easily fall into a state of insufficient energy intake, and that higher body weight would further contribute to a negative energy balance.

In July, this school provided online learning resources for students to follow at home, including physical education. Students stayed active by attending lessons, doing homework, exercising at home, or doing housework. In addition, some students did part-time jobs or took part in outdoor activities that helped them maintain higher levels of physical activity. The energy gaps at different levels of PAL are shown at Figure 2.

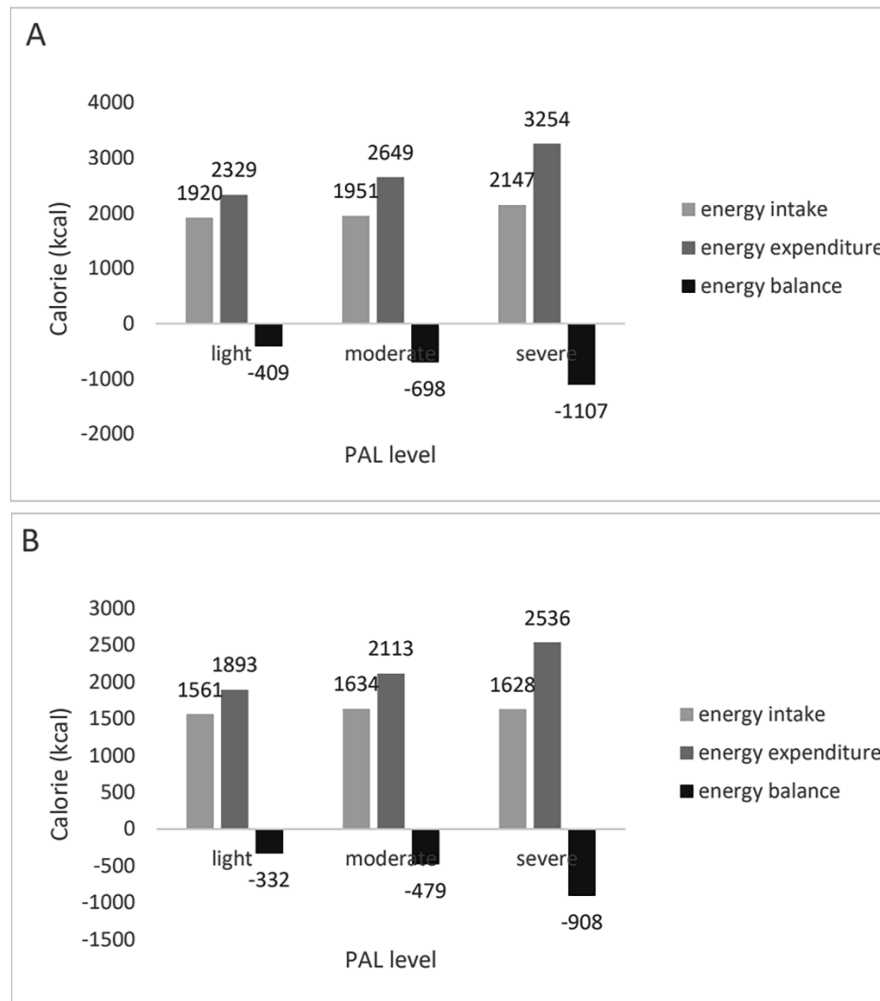


Figure 2. Total energy intake, total energy expenditure and energy balance in different levels of physical activity level (PAL) in males (A) and females (B).

For males, the mean energy intake in the light, moderate and severe PAL groups was 1920, 1951 and 2147 kcal respectively, which was lower than the estimated energy requirement (2300, 2650 and 3050 kcal, respectively)¹⁰. For females in the light, moderate and severe PAL groups, the mean energy intake was 1561, 1634 and 1628 kcal respectively, which was also lower than the estimated energy requirement (1700, 2000 and 2300 kcal, respectively). A few studies have begun to focus on female thinness. Further studies are needed to identify the presence of health risk behaviors in thin young Japanese males, especially those with higher physical activity levels.

It has been reported that an increase in body weight due to increased energy intake does not result in the stimulation of energy expenditure as a compensatory mechanism²². The findings of our study were in

agreement in that neither the number of meals nor calories per meal was significantly associated with the energy expenditure. This indicated that the participants had a weak ability to balance their diet and physical activity spontaneously.

Strengths and Limitations

To our knowledge, this is the first study to examine the energy balance of Japanese university students during the COVID-19 pandemic. Furthermore, few studies have reported the energy balance of young Japanese males. In fact, the energy intake was inadequate in both young females and young males. One important limitation of this study is that the dietary and physical activity data were self-reported which might have added to the variance in the energy balance. The lack of valid and reliable measures of the

energy balance influences the study of energy balance. In our study, all participants were taught how to complete the survey recording forms and the accuracy and completeness of all records was checked by researchers. Furthermore, the predicted resting metabolic rate and thermic effect of food rather than measured data were used to calculate the energy expenditure and PAL because of the limitations imposed by the COVID-19 epidemic. Finally, we lack data before the pandemic, so that we cannot compare the effects of the pandemic on energy balance.

In conclusion, high levels of physical activity were not positively associated with a high energy intake per body weight, which aggravated the negative energy balance in the subjects of our study. Further studies are needed to identify methods for improving dietary habits especially in individuals with higher PAL levels.

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