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RESEARCH ARTICLE

Screening for Relative Energy Deficiency in Male Volleyball Players and the Usefulness of Accelerometers

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Abstract

In recent years, thinness has become a concern in athletes worldwide. The International Olympic Committee has proposed the concept of relative energy deficiency and sounded warnings about the importance of energy intake commensurate with energy expenditure due to exercise. However, it has been suggested that it is difficult to assess this energy intake and consumption in sports. Therefore, this study screened male volleyball players for relative energy deficiency, measured their energy expenditure using accelerometers, and examined the usefulness of accelerometers in sports settings.

Methods: The subjects were 10 males who belonged to a working volleyball team. Their height, weight, body fat percentage, lean body mass, basal metabolic rate, hemoglobin concentration, and bone density were measured before early morning practice. To measure activity, players were asked to wear an activity meter during practice time.

Result: Screening assessment standards have not been presented in Japan. Therefore, we used the value of adult BIM < 17.5 kg/m² used by the American College of Sports Medicine as the first stage of screening for available energy deficiency. No player had a BMI of < 17.5 kg/m². In addition, no athlete had a hemoglobin concentration of < 13.0 g/dl.

Discussion: All athletes measured in this study answered that they did not know their own daily energy consumption. Considering the paucity of data on male volleyball players and the concern about the lack of available energy, it is considered effective to prevent the lack of available energy by proactively measuring it if an activity meter is available for the sport.

Keywords

Athlete, Available energy, Activity mater

Introduction

Basal metabolism is defined as the minimum energy expenditure required to maintain vital activities when awake. However, the measurement of basal metabolism using the indirect calorimetry method is limited by various factors, making it difficult to control the measurement conditions for well-equipped institutions and athletes. In addition to actual measurements, estimation formulas based on previous findings are widely used in nutritional guidance in the field. The Japan Institute of Sports Sciences (JISS: JISS offers support and research in sports science, medicine and information to enhance the performance of Japanese top athlete' performance enhancement) equation is mainly used to estimate basal metabolism in Japanese male athletes, and according to a study by Koshimizu [1] showing the relationship between basal metabolism and lean body mass in male athletes by sport, the intercept of the regression equation by sport ranged from -419 to 388 kcal. The effect of this relationship may be significant when divided into the following two categories. However, the basal metabolism per lean body mass of elite athletes is 29.3 kcal/FFM kg/day [2], 29.4 kcal/FFM kg/day [3], which approximates the JISS equation. Therefore, the JISS formula is often used for male athletes.

In recent years, emaciation has become a growing concern in the world of athletes. The International Olympic Committee [4] has proposed the concept of relative energy deficiency in sport (RED-S), stating that "for all athletes, including male athletes, relative

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energy deficiency has a negative impact on growth and development, metabolism, mental, cardiovascular, bone, and other aspects of the body, resulting in decreased performance [4]. The concept of energy intake and consumption is a key concept for all athletes, including male athletes, and it is important for all athletes to understand the importance of energy intake in relation to energy expenditure during exercise. However, it is difficult to assess energy intake and energy consumption in a sports field.

Recently, accelerometer-based assessment has been utilized as a simple method to measure physical activity intensity and time [5-8]. Chen and Sun [9] reported a high correlation between actual measured daily energy expenditure by a metabolic chamber and daily energy expenditure by accelerometer [10]. Freedson, et al. [11] also measured oxygen consumption during treadmill walking and ambulation and reported a high correlation between accelerometer output and oxygen consumption. Therefore, it is considered to be a useful method for easily measuring daily energy expenditure and physical activity intensity. In previous studies on energy expenditure using accelerometers, measurements have been made in obese [12] and diabetic patients [13], but few studies have evaluated activity intensity in athletes.

In the present study, we screened male volleyball players for relative energy deficiency by measuring body composition and activity level and examined the usefulness of accelerometers.

Research Methods

Subjects

The subjects were 10 males (age: 23-27 years) who belonged to a working adults' volleyball team. The subjects of this study were given a thorough verbal explanation of the purpose and content of the study, and consent for voluntary participation in the study was obtained. This study was reviewed and approved by the Research Ethics Committee of Osaka Aoyama University (No. 0412).

Morphometric measurements

The following morphometric measurements were obtained: Height, weight, lean body mass, fat mass, body fat ratio, basal metabolic rate, bone mineral density, and hemoglobin concentration. Height was measured using a height meter, and weight, lean body mass, fat mass, body fat ratio, and basal metabolic rate were measured by the impedance method using a body composition measuring device (Body Composition MC-780, TANITA). The bone density was measured using an ultrasonic bone mass measuring device (Benus, TANITA Co., Ltd.). The hemoglobin concentration was measured using a noninvasive hemoglobin measuring device (Astrium, Sysmex Co., Ltd).

Bone mineral density measurement

The bone area ratio (BAR, %) was used. This indicator is the area ratio (%) of the trabecular bone cross-section occupied by the bone trabeculae. It is calculated by measuring the ultrasonic drop time in the calcaneal bone width and the calcaneal bone and determining the sound velocity of the calcaneus from these measurements. The measuring instrument used in this study (Benus) demonstrates a close correlation with both the lumbar spine frontal bone mineral density (L2-L4 Bone Mineral Density: BMD) by dual energy X-ray absorptiometry (DXA) and also with the calcaneal bone mineral density, $r = 0.77$ ($p < 0.01$) and $r = 0.83$ ($p < 0.01$), respectively [14]. The measurement site was the right calcaneus. The coefficient of variation for the same site measurement was 1.4% [14].

Measurement of energy expenditure during volleyball training

In this case, we measured the intensity of exercise during practice and the intensity and duration of exercise during training on weekdays. The intensity of exercise during volleyball training was measured using an activity meter (Active style Pro HJA-750c; OMRON Corporation). The Active style Pro HJA-750c has a built-in 3-axis acceleration sensor, which estimates the intensity of exercise every 10 seconds based on the composite acceleration of the 3 axes and can identify a physical activity level (METs) of 0 to 18 [11,15]. However, it does not measure the amount of activity of an athlete. This activity meter was attached to the subject's right ankle using a specially-made ankle band. Because of the nature of the volleyball game, it was determined that wearing the device on the upper body or upper extremity would be dangerous, so the device was worn on the right ankle for safety during exercise. The activity meters were distributed to the subjects before practice and collected after practice.

Simple Questionnaire

1. Do you know your energy consumption?
2. Are you conscious about what you eat?
3. What do you practice?

Formula for estimated energy consumption (JISS Method)

Lean body mass (LBM) × 28.5 × PAL = Estimated energy requirement

PAL for ball games is 2.0 (seasonal) and 1.75 (off-season)

Statistical Processing

All values for each item in this study are presented as the mean and standard deviation. Student's t test was used for comparisons between groups, and the significance level was set at < 5%.

Table 1: Physical characteristics of the subjects.

		Middle blocker (n = 8)	Libero (n = 2)
Age	Year	24.8 ± 2.1	26.0 ± 1.4
Height	cm	192.4 ± 4.1*	174.0 ± 1.4
Weight	kg	84.5 ± 7.1*	70.5 ± 2.1
Fat	%	11.2 ± 2.7*	9.6 ± 1.8
FFM	kg	74.9 ± 5.0*	63.8 ± 3.2
BMI	kg/m²	22.8 ± 1.9	23.3 ± 0.3
hemoglobin	g/dl	15.2 ± 1.4	14.4 ± 1.3
BAR	%	38.4 ± 2.3	36.3 ± 7.8
BMR	kcal	2186.8 ± 166.2*	1813.0 ± 90.5

FFM: Fat Free Mass; BMI: Body Mass Index; BMD: Bone Material Density; BMR: Basal Metabolic Rate

*: vs. Libero, $p < 0.05$

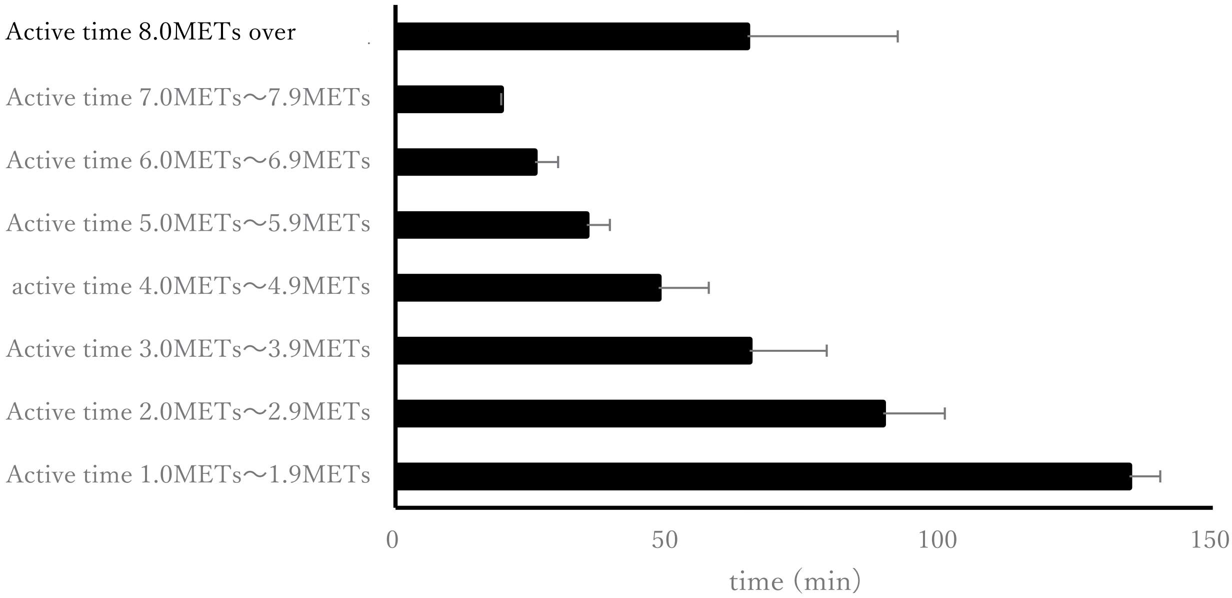

Figure 1: Activity meter results.

Results

The physical characteristics of the subjects are shown in Table 1.

A significant difference in height was observed between Middle blocker (MD) and Libero (L) groups with individuals in the MD group being significantly taller than those in the L group. The overall mean was 188.7 ± 8.6 cm. The weight of the MD group was significantly heavier than the L group. The overall mean was 81.7 ± 8.6 kg. The body fat ratio of the MD and L groups did not differ to a statistically significant extent. The lean body mass of the MD group was significantly greater than that of the L group. The BMI of the groups did not differ to a statistically significant extent, with an overall value of 22.9 kg/m². Screening evaluation criteria have not been shown in Japan. Therefore, we used the value for adults of BIM ≤ 17.5 kg/m², which is used by the American College of Sports Medicine as the first stage of screening for available energy deficiency. We found no athletes with a BMI ≤ 17.5 kg/m² and no athletes with available energy deficiency.

The hemoglobin concentration did not differ between the MD and L groups. Furthermore, all athletes had a hemoglobin concentration of ≥ 13.0 g/dl (WHO). However, one player was using iron supplements on a daily basis.

The BAR did not differ between the MD and L groups, with a mean value of 38.0 ± 3.4%.

The results for physical activity are shown in Table 2 and Figure 1.

The basal metabolism was of the MD group significantly higher than that of the L group. The overall mean was 1830.9 ± 140.2 kcal. The energy expenditure from exercise did not differ to a statistically significant extent between the MD and L groups, with an overall mean of 2291.2 ± 159.2 kcal. The total energy expenditure while wearing the device was significantly higher in the MD group than in the L group. The overall mean was 4427.5 ± 259.6 kcal, and the duration for

Table 2: Activity meter results.

	Middle blocker (n = 8)	Libero (n = 2)
BMR (kcal)	1863.9 ± 90.0	1594.5 ± 27.6
Energy consumption (kcal)	2313.1 ± 148.9	2150.0 ± 237.6
Total energy consumption (kcal)	4487.8 ± 199.8*	4010.5 ± 295 .8
Set up time (min)	479.5 ± 18.5	493.0 ± 21.2

BMR: Basal Metabolic Rate; *: vs Libero, $p < 0.05$

which the activity meter was worn was approximately the same in the groups (482.2 ± 18.7 minutes).

Questionnaire Results

The results of the players' questionnaire were as follows: 1) Ten players answered "I do not know" when asked if they knew their energy consumption; 2) Ten answered "Yes" when asked if they were conscious of their dietary needs; 3) In response to the question of whether they were conscious of their dietary needs, nine players said what they were conscious of their diet; five answered "not too much fat"; two answered "balanced diet"; three answered "carbohydrates"; and four answered "no". Two respondents answered, "I eat a well-balanced diet," and three answered, "I eat carbohydrates. One respondent answered, "I reduce carbohydrates".

Discussion

In Japan, there are limited data on the physical characteristics and energy consumption of male volleyball players. Therefore, we screened male volleyball players for relative energy deficiency and measured their actual energy consumption to examine the usefulness of accelerometers.

The average BMI of the 10 athletes was 22.9 ± 1.7. There are no screening criteria for insufficient available energy in Japan. Thus, we used the primary screening criterion used by the American College of Sports Medicine, a BMI of < 17.5 kg/m² [3]. As a result, all athletes had a BMI of ≥ 17.5 kg/m², which is not considered to be an available energy deficiency. In recent years, energy deficiency among elite male volleyball players has been reported in other countries [16,17]. Players with a BMI of 18.6 kg/m² were found in this study. Bandyopadhyay [18], measured the body composition of Indian volleyball players and reported a BMI of 19.59 ± 1.57 kg/m². It has been reported that volleyball players' body shape changes with positional changes at different levels of competition (e.g., state, national, international), depending on the technical and strategic demands placed on the players [19,20].

The BMI in this study was considered common for volleyball players.

The overall mean body fat percentage was 10.9 ± 2.6%. Bandyopadhyay, et al. reported a value of 10.04 ± 2.98%, which is typical for volleyball players. However, Koizumi, et al. [21] reported a body fat percentage of 12.6% for male Japanese college volleyball players. In comparison to the Japanese population, the body fat percentage of the subjects in this study was low. This may be attributed to the high performance level of the subjects.

Previous studies have shown that bone mass is correlated with body mass (e.g., body weight, BMI or lean body mass) [22,23]. On the other hand, Inaba, et al. [24] reported that none of the correlation coefficients between BAR and body weight used to index bone mass showed significant correlations. Similar to Inaba, et al., the present study found no significant correlation between BAR and body size. Inaba, et al. [24] stated that this was because previous studies were not conducted on athletes. The present study analyzed athletes, and the results were in line with those of Inaba, et al.

We examined whether the estimated energy requirements of the JISS method used in Japan approximated the values measured by body composition analyzers and accelerometers.

Koizumi [21] noted that appropriate adjustments should be made in the case of athletes, as there are variations depending on the characteristics of their sport and the nature of their daily training. In the case of volleyball, the game may last from less than one hour to two hours, the practice time should correspond to the length of the game, and the intensity of the activity, such as spiking and jumping, should be adjusted accordingly. In addition, the intensity of the activity is intermittent high-intensity exercise, such as repeated spiking and jumping, which requires an energy intake of at least 3,000 kcal/day. Based on the values in the article, we calculated the estimated energy requirement using the JISS method and found it to be approximately 3431 kcal. Although this difference of approximately 400 kcal seems small, it would require an increase of approximately 1000 kcal from the amount of energy the subjects were consuming. Considering this difference, when possible, it would be useful to regular measure events by an activity meter.

In the present study, we compared the basal metabolism determined by a body composition analyzer, the estimated energy requirement determined by the JISS, the basal metabolic rate determined by an activity meter, the energy expenditure by exercise, and the total energy expenditure when wearing the activity meter.

Significant differences were found between the basal metabolic rate determined by the body composition analyzer and the value determined by the activity meter. While no significant difference was found between the basal metabolism determined by the body composition meter and the JISS method, a significant difference was found between the values determined by the accelerometer and those determined by the activity meter. The reason for this may be that the activity meters are for research purposes and not for athletes.

The energy expenditure of the exercise measured by the accelerometer was 2291.2 ± 159.2 kcal. When added to the basal metabolic rate of body composition and the JISS formula, they were 4403.2 ± 306.5 kcal and 4362.0 ± 277.1 kcal, respectively. These values were not significantly different from the estimated energy requirement (4141.6 ± 370.9 kcal/day) obtained by the JISS formula. The total calories when worn (4427.4 ± 259.6 kcal) were not measured for one day. However, it did not differ to a statistically significant extent from the estimated energy requirement determined by the JISS formula and the basal metabolic rate calculated by the body composition analyzer combined with the energy expenditure of exercise measured by the activity meter. However, since the athletes were only wearing the device for 400-500/1440 minutes, it can be inferred that the energy consumption would increase when considered as a single day.

Accelerometers have been reported to show errors with increasing METs and to underestimate activity in comparison to the DLW method [25]. In this case study, 3 out of 10 subjects showed a large difference between the estimated energy requirement obtained from the JISS method and the actual measured value (-751 to -582 kcal). Although accelerometers can measure from 0 to 18 METs, the activity times were categorized as 1-2 METs, 2-3 METs, 3-4 METs, 4-5 METs, 5-6 METs, 6-7 METs, and ≥ 8 METs, as shown in Figure 1. The three athletes with the highest energy consumption were active longer than the others, as indicated by their METs value of ≥ 8, which may have been a factor. It is also inferred that there was a lower degree of underestimation in this study.

It is not necessary to know the exact amount of energy consumed. However, all of the athletes evaluated in this study indicated that they did not know their energy consumption. In the prevention of relative energy deficiency, knowing one's energy expenditure is very important for growth and performance improvement. Although there are some limitations (e.g., not being able to get the accelerometer wet), in sports in which measurement does not interfere with practice (e.g., volleyball), the active incorporation of this information would be useful for preventing a lack of available energy.

The team of athletes investigated in this study did not provide dietary intervention due to the stress on the athletes. In addition, they did not cooperate with the dietary survey. Therefore, no dietary survey was conducted, and it is not possible to determine whether the athletes had an energy intake commensurate with the energy consumed by their activity. Further work is needed to measure energy consumption and to compare both energy intake and energy consumption.

Conclusion

An athlete may not know his/her own daily energy expenditure. Considering the concern about the lack of available energy, it is considered effective to prevent the lack of available energy by proactively measuring it if an activity meter is available for the sport.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

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Competing Interests

The authors declare that they have no competing interests.

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