It has been reported that the physical fitness of adolescents has been decreasing gradually over the past twenty years in Japan. The reasons for this decrement were a decrease in physical activity and an increase in the prevalence of obesity. However, there is no clear evidence on the relationships between physical activity and physical fitness or body composition for adolescents. The purpose of this study was to measure the total energy expenditure (TEE), physical activity level (PAL) and times spent in light, moderate and vigorous physical activity and to ascertain relationships between physical activity and physical fitness, and body composition for adolescents. Twenty four male adolescents (age: 17.3±1.3) volunteered for participation. Subjects assigned as trained adolescents group (n=16) and untrained group (n=8). TEE was measured by doubly labeled water method and times spent in physical activity were assessed by accelerometer method. VO2 max was indirectly measured by breath-by-breath method with stepwise incremental cycle ergometer exercise test. Measurement of physical fitness tests was conducted according to the Ministry of Education, Culture, Sports, Science and Technology. TEE and PAL were significantly higher in trained adolescents (4813±439 kcal/day and 2.64±0.14) than untrained (2859±147 kcal/day and 1.84±0.16), respectively. Times spent in light, moderate and vigorous activities measured from accelerometer were significantly higher in trained adolescents than untrained, while times in sedentary activity were significantly higher in untrained adolescents than trained. PAL and times spent in physical activity (light, moderate, vigorous) were significantly correlated with physical fitness (VO2 max, sit-ups and sitting trunk flexion). Additionally, times spent in moderate related to 20-meter shuttle run. However, PAL and times spent in physical activity were not significantly related to %body fat. These results indicated that daily sport activity results in significant difference of activity energy expenditure between trained and untrained adolescents, and that increase in PAL and times spent in physical activity while engaging in daily sport activity would contribute to improvement of health-related fitness in adolescents.

Keywords: Adolescents, Regular sport activity, Physical fitness, Percent of body fat, Doubly labeled water method
1. Introduction

Current data show that the physical fitness of both male and female adolescents has long been decreasing compared to that of 20 years ago in Japan. This tendency is particularly significant regarding endurance and flexibility (Ministry of Education, Culture, Sports, Science and Technology: MEXT, 2005). For instance, the average time in endurance running (1500m for boys and 1000m for girls) for 17-year olds has been decreasing since 1970, while the standard deviation has been getting larger (Nisijima, 2002). This indicates that the disparity in the physical fitness among adolescents might become more prominent every year. In addition, it is reported that the physical fitness reaches a peak at the age of 17 and then declines (Nishijima, 2002). The maximal oxygen uptake ($V_{O_{2}}_{\text{max}}$), which is concerned to lifestyle-related diseases, is particularly noted as showing a lower value if proper exercise is not performed during adolescence when the trainability is higher (Kobayashi, et al., 1979). Moreover, schoolchildren with less physical fitness tend to be overweight which is considered to be one of the factors of low physical fitness (Kin, et al., 1992). Thus, the decline in physical fitness and the increase in obesity during adolescence has become a difficult problem to solve not only in Japan but also in other developed countries, and there is concern that it might affect their future health.

In consequence, a number of study reports, both domestic and international, have examined the relationship between physical activity and physical fitness or body composition in adolescents (Miyashita, 1983; Naka/Demura, 1994; Morrow and Freedson, 1994; Uechi, et al., 2002). Most of these previous studies have different evaluation indicators including the time engaging in physical activity, time spent watching television and participation in sports, and they tend to evaluate physical activity only from a single viewpoint. Today, however, since it is undeniable that the convenience in transportation may be causing the decline in daily physical activity, the decline in physical fitness of adolescents cannot be ascribed to the decrease in specific physical activity such as sports. Therefore, it is presumed to be significant to evaluate total amount of physical activity including daily physical activity, and to investigate the relationship between the amount of physical activity and physical fitness. Essentially, it seems preferable that a better indicator of the amount of physical activity is based on energy metabolism in vivo corrected by the physical constitution and body composition of each individual. The activity record method and the heart rate method are recommended as the major evaluating methods (Katzmarzyk, et al., 1998; Ekelund, et al., 2001; Huang and Malina., 2002). However, it is noted that the activity record method may cause fluctuation in the accuracy of recorded activity content depending on the subject. Additionally, while the energy expenditure is calculated based on METs, it is a concern that some error might occur between the predicted value and the real energy expenditure of each individual when the METs Compendium reported by Ainsworth, et al., (2000) is applied. Because, resting metabolic rate is found to have differences among individuals and the economic efficiency in performance is different for the same activity (Byrne, et al., 2005; Harrell, et al., 2005).

Similarly, it is reported that the accurate measurement of energy expenditure for physical activity has its limitations, even when the relational expression between heart rate and oxygen uptake is created for individual in the heart rate method (Ebine, et al., 2002; Hikihara, et al., 2005). Given this, this study measured the total energy expenditure (TEE) more accurately by using the doubly labeled water (DLW) method which is the golden standard of energy expenditure measurement in the field, and then calculated physical activity level (PAL), which is the indicator of the amount of physical activity, by dividing TEE with basal metabolic rate (BMR). At the same time, intensity and time spent for physical activity in one day was measured by accelerometer. The purpose of this study was to examine the relationship between physical activity, and both the physical fitness and percent of body fat with considering regular sports activity (participation of a sport club or not).

2. Methodology

2.1. Subjects

Subjects were male adolescents, from first year high school students to university freshmen (average age: $17.3\pm1.3$ yrs), consisting of 16 boys who regularly participate in a sports activity (trained group, average age: $16.5\pm0.5$ yrs) and 8 boys who
did not participate in any sports activity for at least more than a year (untrained group, average age: 18.6 ±0.5 yrs). Physical characteristics of subjects are shown in Table 1. The subjects and their parents were fully apprised of the purpose and contents of this experiment, and the measurement started after they signed a letter of consent. In addition, this study was conducted with the approval of the Research Committee of the Graduate School of Comprehensive Human Sciences, University of Tsukuba.

2.2. Experiment Protocol

2.2.1. Evaluation of Physical Activity

(1) Measurement of Total Energy Expenditure

The DLW method was used for the measurement of TEE. In this method, the day to start measurement was defined as Day 1 and the day to end measurement as Day 8, based on the day (Day 0) when the DLW, labeled with Oxygen-18: \( ^{18} \text{O} \) and Hydrogen-2: \( ^{2} \text{H} \) which are stable isotope, was administered (Figure 1). To prepare for DLW administration, urine samplings were taken in order to comprehend the isotope concentration within the body as the baseline on the day before the administration (Day-1) (Figure 1). Then, on the presumption that the total body water (TBW) of a subject is 60% of the weight, the DLW combining 0.12g/kgTBW of \( ^{2} \text{H} \) (99.75atm%) and 2.5g/kgTBW of \( ^{18} \text{O} \) (10.0atm%) was administered orally. In order to avoid heeltap, 100 ml of water was poured into the cup and taken again. After administering DLW, subjects were not allowed to have any food nor drink and were instructed to rest quietly until urine samplings were taken three and four hours later when stable isotopes would be at equilibrium within the body. TBW was calculated from the isotopic ratio of \( ^{18} \text{O} \) in the urine sampling extracted three and four hours later. Further, the second urine sample in the morning was taken on Day 1 and Day 8 to determine the reduction rate of isotopic ratio and to calculate the emission rate of carbon dioxide (rCO\(_2\)) (Ebine, et al., 2000). TEE was calculated from rCO\(_2\) and Food quotient (FQ) based on the dietary record during three days using the following formula made by Weir (1949) (Black, et al., 1986).

\[
\text{[TEE(kcal/day)]} = 3.9 \times \text{rCO}_2 / \text{FQ} + 1.1 \times \text{rCO}_2
\]

For the dietary record, subjects were asked to take photos of what they ate and left by using a digital camera. In addition, a digital cooking scale was used to record the amount of meal removed of the plate. An expert dietitian was in charge to analyze diet records.

Urine samplings and local drinking water were transferred to plastic bottles and sealed off with paraffin film, and then kept in a freezer at -20 °C until analysis. The analysis of the isotopic ratio of administered DLW was based on previous study (Ebine, et al., 2000). Triplicate analysis was carried out on all the samples, and the coefficient of variation (CV) was 0.33% for \( ^{2} \text{H} \) and 0.17% for \( ^{18} \text{O} \), respectively.

(2) Measurement for Intensity and Time of Physical Activity

During measurement using the DLW method, the intensity and the time of physical activity was recorded every four seconds in continuity, using an

<table>
<thead>
<tr>
<th>Physical characteristics of trained and untrained adolescents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trained (n=16)</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Weight (kg)</td>
</tr>
<tr>
<td>FFM (kg)</td>
</tr>
<tr>
<td>Body fat (%)</td>
</tr>
<tr>
<td>BMI</td>
</tr>
</tbody>
</table>

1. FFM: fat free mass, BMI: body mass index
2. # Fat free mass and percent of body fat were calculated from total body water measured using isotope dilution (see Method).
3. * Significant difference between trained and untrained adolescents.

**Table 1**
accelerometer (Suzuken, Lifecorder, Japan) with an acceleration sensor which responds to vertical motion (Figure 1). According to Adachi, et al., (2005), the accelerometer used in this study is useful as an objective indicator because acceleration increases with the increment of speed in walking and running. This study classified the physical activity into eleven levels; sedentary (acceleration intensity: 0-0.5), light activity (1-3), moderate activity (4-6) and vigorous activity (7-9), and then measured the time spent for each activity. Kumahara, et al., (2004) reported that light (<3.0METs), moderate (3.0-6.0METs), vigorous activity (>6.0METs) which were proposed by Pate, et al., (1995) correspond to acceleration intensity 1-3, 4-6 and 7-9, respectively. Subjects were instructed to wear the accelerometer on either side of the hip during daily life except when sleeping or bathing. Since the position of the sensor could affect the acceleration, subjects were also instructed to keep the equipment horizontally and firmly. Along with the measurement by the accelerometer, subjects were asked to record their activity content in a given sheet scaled by minute in order to specify the physical activity of each subject. Subjects were directed to write periodically during resting time etc. It was feared that daily life activity might change when imposed of multiple measurement methods including the DLW method, accelerometer, activity record and dietary record at the same time. Therefore, the period of measurement to wear the accelerometer and to take the activity record was determined to two weekdays and one holiday. (Katzmarzyk, et al., 1998; Huang and Malina, 2002; Montgomery, et al., 2004). In this respect, Rafamantatsoa, et al. (2002) reported that significant correlation \( r=0.78, p<0.05 \) was observed between the TEE measured by the DLW method during 14 days in male adults and the TEE evaluated by the accelerometer only the total of three days including two weekdays and one holiday during the same period.

(3) Calculation of Physical Activity Level and Energy Expenditure due to Physical Activity

The physical activity level (PAL) was used to determine the intensity of daily activity. This indicator is gained by dividing TEE with basal metabolic rate (BMR) and is regarded as an international indicator to evaluate the intensity of daily activity for a wide range of age groups from children to adults (Kashiwazaki, 1997). It is also known to be an accurate method for evaluation, even if the subjects are different in age, sex, weight and body composition. Meanwhile, the activity energy expenditure (AEE) was calculated by reducing BMR and the diet–induced thermogenesis (DIT) from TEE. DIT was determined to be 10% of TEE (Maffeis, et al., 1993).

2.2.2. Measurement of Basal Metabolic Rate

Subjects were instructed to come to the experimental laboratory early in the morning with fasting in the last 12 hours. Subjects were also directed to come to the laboratory on foot or by car in order to avoid vigorous motion. After arriving at the laboratory, subjects were kept at rest for 20 minutes in supine position. Then the expired gas analyzer (Minato Medical Science Co.,Ltd., AERO MONITOR AE300S) was used to measure oxygen consumption (\( \dot{V}O_2 \)) and carbon dioxide production (\( \dot{V}CO_2 \)) from expired gas volume during 20 minutes at rest. In order to measure the amount of expiratory volume under steady breathing conditions, the data of the first five minutes immediately after starting measurement was excluded from the analysis.

2.2.3. Evaluation of Physical Fitness

(1) Physical Fitness Test recommended by MEXT

Based on the new physical fitness test of the MEXT aimed at students from twelve to nineteen years, the measurement of physical fitness including sit up, 20m shuttle run, sitting trunk flexion, side step, 50m sprint, handball throw, grip strength and standing long jump was conducted. Considering the difference in physical fitness due to the age difference of subjects, the deviation value (T score) for the national average value of each age in the new physical fitness test was calculated and normalized.

(2) Measurement of Maximal Oxygen Consumption

Subjects were asked to conduct incremental-endurance exercise test by using a cycle ergometer (Combi Corporation, AEROBIKE75XL II). Oxygen and carbon dioxide concentrations were measured during the test, incrementing load by 30W every five minutes from the load level at 30W when starting. At the same time, the heart rate (HR) during the test was also recorded continuously by using a heart rate monitor (Polar, Accurex plus). The stage of incrementing load was divided into five levels and a single regression equation was created for each subject based on HR and \( \dot{V}O_2 \), during last one minute (4 min-5 min). The estimated maximal heart rate
(220-age) was assigned to the single regression equation, and the maximal oxygen uptake per weight ($V_o_{max}$) was predicted.

### 2.2.4. Measurement for percent of Body Fat

Urine samplings were taken at three and four hours after the administration of DLW and a diluting volume of $^{18}$O was measured to calculate TBW (Racette, 1994). Then under the assumption that the water content rate in fat free mass (FFM) is 73.2 % (Pace and Rathbum, 1949), FFM was estimated from TBW. FFM was reduced from the weight to calculate the body fat (BF), and %BF was determined.

### 2.3. Statistical Analysis

Measured values are shown by mean value ± standard deviation (Mean±SD). The un-paired t test was used for the significance test of mean values between the trained group and the untrained group. Since the normal distribution of samples in this study was not acknowledged, Spearman's rank order correlation analysis was used to test the relationship among each item. JMP 5.0.1 (SAS, Institute Japan, Tokyo) was used in each statistical analysis. A significance level was set below 5 % in each case. In addition, one subject among the trained group suffered injury to a ligament during the measurement period, and subsequently the relevant data was excluded from the statistical analysis.

### 3. Results

In terms of all TEE, BMR, AEE and PAL of subjects, the trained group showed significantly higher values compared to the untrained group (Table 2).

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Total energy expenditure (TEE), basal metabolic rate (BMR), activity energy expenditure (AEE), and physical activity level (PAL) in trained and untrained adolescents.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trained (n=15)</td>
</tr>
<tr>
<td>TEE (kcal/d)</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>BMR (kcal/d)</td>
<td>1822 ± 137</td>
</tr>
<tr>
<td>AEE (kcal/d)</td>
<td>2510 ± 297</td>
</tr>
<tr>
<td>PAL (TEE/BMR)</td>
<td>2.64 ± 0.14</td>
</tr>
</tbody>
</table>

* Significant difference between trained and untrained groups.

The trained group was superior to the untrained groups in all the measured items of physical fitness in comparison with the untrained group. The significant difference was observed in $V_o_{max}$, sit up, 20m shuttle run and sitting trunk flexion in particular between the trained and the untrained groups, respectively (Table 3).

After reviewing the relationship among each measured item of physical activity, physical fitness and %BF, significant positive correlation were observed between PAL and $V_o_{max}$, sit up or sitting trunk flexion (Table 4). In addition, significant positive correlation were observed between $V_o_{max}$, sit up or sitting trunk flexion and the time spent for the "sedentary" activity, while significant positive correlation was observed between each of them and the time spent for "light", "moderate" and "vigorou" activity in either cases. With regard to the 20m shuttle run, significant positive correlations were observed only with the time spent for "moderate" activity (Table 4). Significant correlation, however, was not observed between physical activity and %BF (Table 4).

After reviewing the relationship between PAL and the time spent for "light", "moderate" and "vigorou" activity, significant positive correlations were observed in each case (light: $\rho=0.87$, moderate: $\rho=0.59$, vigorous: $\rho=0.63$, $p<0.01$).

### 4. Some Considerations

#### 4.1. Difference in Total Energy Expenditure and Physical Activity Time due to Regular Sport Activity

It has been suggested that exercise in daily life may lead to increase TEE and PAL (Blaak, et al., 1992; Van Etten, et al., 1997). In contrast, several
studies reported the result that TEE and PAL would not change or would decrease according to the age of subjects and the content of intervention exercise (Goran, et al., 1992; Meijer, et al., 1999). These studies concluded that fatigue might suppress daily physical activity other than intervention exercise. Therefore, a conclusion has not yet been established with regards to the influence of exercise on TEE, PAL and daily physical activity. In addition, the number of studies targeting adolescents is distinctly small (Blaak, et al., 1992). In this study, TEE of both groups was obviously different due to regular sport activity, resulting with the values of PAL, 2.64 ±0.14 for the trained group and 1.84±0.16 for the untrained group. According to "Dietary Reference Intakes recommended by Ministry of Health, Labour and Welfare for 2005" (Daiichi-shuppan editorial department, 2005), the values of trained group showed higher values than "high" (III: 1.90-2.20) and the values of untrained group corresponded to "moderate" (II: 1.60-1.90). The AEE for the trained group was 2510±297 kcal (51 % of TEE) and 1008±145 kcal (35%) for the untrained group, which shows the difference between both groups with reaching 1502 kcal/day. It is supposed that the main causes for such a large difference between the groups would include the facts that the average exercise time with rest was as long as 5 hours in a day in the trained group. Besides, the difference was caused from the habit that all 15 subjects in the trained group did running or cycling (time: 29.6±12.2min/d on average) on their way between school and home. In contrast, two subjects among eight in the untrained group walked to school (4.5±0.7min/d) and the other 6 subjects rode to school on bicycle (8±2min/d). Thus, it is assumed that the difference in AEE was caused mostly by the energy expenditure during sport club activity and commuting to and from school. This is also supported by the fact that the trained group showed significantly higher values in the time spent for "light", "moderate" and "vigorous" activity in a day compared to untrained group, and that the time spent for standing and seated activity (sedentary) is distinctly longer in the untrained group compared to the trained group (Figure 2). Assuming that the time spent for "moderate" and "vigorous" activity corresponds to the main exercise during sport club activity, it seems reasonable that the time spent for "moderate" and "vigorous" activity for the trained group was longer than the untrained group. The time spent for "light" activity, however, also showed large differences between the groups. The "light" intensity determined by the accelerometer corresponds to 1.8-3METs (Higuchi, et al., 2003; Kumahara, et al., 2004), which is relevant to the physical activity such as "standing", "tidying", "cleaning" and "very slow walking". In fact, the "light" intensity includes "movement to the school ground", "grounds-keeping", "preparation and clearing of exercise equipment" and "warming-up

![Figure 2](http://www.soc.nii.ac.jp/jspe3/index.htm)
Relationships between Total Energy Expenditure and Both Physical Fitness and Body Fat

Table 3 Physical fitness in trained and untrained adolescents.

<table>
<thead>
<tr>
<th></th>
<th>Trained (n=15)</th>
<th>Untrained (n=8)</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>VO₂max (ml/kg)</td>
<td>66.6</td>
<td>8.7</td>
<td>53.5</td>
</tr>
<tr>
<td>sit-ups (frequency)</td>
<td>43 [70.5]</td>
<td>5 [7.0]</td>
<td>30 [52.1]</td>
</tr>
<tr>
<td>20m shuttle run (frequency)</td>
<td>132 [66]</td>
<td>11 [3.8]</td>
<td>93 [55.3]</td>
</tr>
<tr>
<td>sitting trunk flexion (cm)</td>
<td>60 [58.8]</td>
<td>8 [7.0]</td>
<td>45 [47.6]</td>
</tr>
<tr>
<td>side steps (frequency)</td>
<td>62 [60.2]</td>
<td>3 [4.3]</td>
<td>57 [53.4]</td>
</tr>
<tr>
<td>50m sprint (sec)</td>
<td>7.1 [53.5]</td>
<td>0.4 [6.5]</td>
<td>7.4 [50.6]</td>
</tr>
<tr>
<td>grip strength (kg)</td>
<td>47 [56.2]</td>
<td>6 [8.2]</td>
<td>45 [51.0]</td>
</tr>
<tr>
<td>standing long jump (cm)</td>
<td>231 [52.2]</td>
<td>22 [8.3]</td>
<td>229 [49.1]</td>
</tr>
<tr>
<td>total points of physical fitness</td>
<td>67 [62.6]</td>
<td>5 [4.8]</td>
<td>54 [51.4]</td>
</tr>
</tbody>
</table>

1. The values in parentheses in physical fitness variable were normalized by T score.
2. * Significant difference of values normalized by T score between trained and untrained

Table 4 Spearman’s rank order correlation coefficients between physical activity and both physical fitness and percent of body fat.

<table>
<thead>
<tr>
<th></th>
<th>PAL</th>
<th>sedentary</th>
<th>light activity</th>
<th>moderate activity</th>
<th>vigorous activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO₂max</td>
<td>0.50*</td>
<td>-0.59*</td>
<td>0.60*</td>
<td>0.60*</td>
<td>0.62*</td>
</tr>
<tr>
<td>sit-aps</td>
<td>0.66*</td>
<td>-0.56*</td>
<td>0.51*</td>
<td>0.59*</td>
<td>0.61*</td>
</tr>
<tr>
<td>20-meter shuttle run</td>
<td>0.38</td>
<td>-0.25</td>
<td>0.31</td>
<td>0.24</td>
<td>0.37</td>
</tr>
<tr>
<td>sitting trunk flexion</td>
<td>0.58*</td>
<td>-0.57*</td>
<td>0.46*</td>
<td>0.49*</td>
<td>0.51*</td>
</tr>
<tr>
<td>side steps</td>
<td>0.20</td>
<td>-0.30</td>
<td>0.01</td>
<td>0.34</td>
<td>0.35</td>
</tr>
<tr>
<td>50-meter sprint</td>
<td>0.03</td>
<td>-0.04</td>
<td>-0.10</td>
<td>0.10</td>
<td>0.11</td>
</tr>
<tr>
<td>handball throw</td>
<td>0.001</td>
<td>0.001</td>
<td>0.02</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td>grip strength</td>
<td>0.04</td>
<td>-0.26</td>
<td>0.04</td>
<td>0.32</td>
<td>0.28</td>
</tr>
<tr>
<td>standing long jump</td>
<td>0.08</td>
<td>0.02</td>
<td>0.01</td>
<td>0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>total points</td>
<td>0.33</td>
<td>-0.29</td>
<td>0.21</td>
<td>0.37</td>
<td>0.34</td>
</tr>
<tr>
<td>% Body fat</td>
<td>0.01</td>
<td>0.03</td>
<td>0.06</td>
<td>0.03</td>
<td>-0.08</td>
</tr>
</tbody>
</table>

1. PAL: physical activity level
2. * Significant correlations (p<0.05)
3. n=23

The activities often take place during periods other than sport club activity (training) in the trained group, according to the activity record. This suggests that sports activity exercise could increase not only the energy expenditure through the main exercise but also through the accompanying physical activity (movement, preparation and clearing) and contribute to the increase in PAL. This is consistent with the result that a significant correlation (r=0.87, p<0.01) was observed between the time spent for "light" activity and PAL. Westerterp, et al., (2001) reported in the study for healthy adult males and females (age: 27±5) that a positive correlation was observed between the time spent for moderate intensity activity and PAL evaluated by the DLW method. However, it was also reported that a negative correlation was observed between the time spent for low intensity activity and PAL, which differs from this study. The reason for this could be that Westerterp, et al., (2001) investigated the relationship between the ratio of the time spent for physical activity during daytime and PAL, while this study evaluated the time spent for physical activity in one day (24 hours). In addition, it is also speculated as the reason that whereas Westerterp, et al., (2001) used an accelerometer which measures three dimensional acceleration as metric variables, the one-dimensional accelerometer used in this study classifies only the physical activity mainly associated with walking and running into "light", "moderate" and "vigorous" in principle. Besides, the "light" activity determined in this study does not include the resting state in seated or supine position. Lazzer, et al., (2005) conducted an exercise intervention program in adolescents (age: 12-16) for eight months, and reported that the time spent for rest in a seated position decreased and the time spent for low and medium intensity activity (changing clothes, cooking, cleaning, walking and recreation sports etc.) increased. According to these results, it is undeniable that the daily sports activity not only increases the energy expenditure due to main exercise but also could affect other physical activity synergistically to bring substantial difference in AEE.

4.2. Physical Activity Condition and Physical Fitness

Huang and Malina (2002) reported that significant correlations were observed between TEE estimated by the activity record method and both 1 mile running and sitting trunk flexion, respectively. The other studies, however, do not always agree in the conclusion on the relationship between physical activity and physical fitness (Morrow and Freedson, 1994; Katzmarzyk, et al., 1998; Rowlands, et al., 1999; Ekelund, et al., 2001). Those previous studies used the estimation method in evaluating physical activity, and it is assumed that in this study, the method could have some problem in accuracy, which caused the inconsistency. Therefore, PAL was calculated from TEE evaluated by using the DLW...
method, and its relationship with physical fitness was examined. As a result, significant correlations were observed between PAL and $\dot{V}_O_2_{\text{max}}, \text{sit-up or sitting trunk flexion (Table 4).}$ Since these items of physical fitness are emphasized as elements of health related fitness (Aoki, 1993), the result of this study suggests the possibility that the increase in energy expenditure accompanying regular sports activity could be important in maintaining and improving health and physical fitness for adolescents. These results supports the study reports in male and female of 9-18 years of age by Katzmarzyk, et al., (1998), Ekelund, et al., (2001) and Huang and Malina (2002). Significant correlation were also observed between the time spent for "light", "moderate" and "vigorous" activity, and $\dot{V}_O_2_{\text{max}}, \text{sit-up or sitting trunk flexion respectively (Table 4).}$ However, the result of this study has a limitation in arguing on the intensity of physical activity because of the number of subjects and the characteristics of the subjects’ distribution. In this study, it is thought that this issue has been already resolved. Because, it has been reported that physical activity with the intensity of more than anaerobic threshold (AT) or with HR at more than 140 continuing more than 20-30 minutes is effective when aiming to improve cardiorespiratory physical fitness (Massicotte and Macnab, 1974; Miyashita, 1983). In fact, while the time spent for "vigorous" activity was $48\pm22\text{min/day}$ in the trained group in this study, the time was as short as $1.4\pm0.5\text{min/day}$ in the untrained group. It is presumable that this difference might be involved with the relative merits in physical fitness. In contrast, it was interested that significant difference was also observed in the time spent for "light" and "moderate" activity and that there were significant relationship between the time spent and the items of physical fitness relating to endurance and flexibility. This fact shows that the daily life activity level of adolescents without regular sports activity is extremely low, suggesting that it might encourage a decrease in physical fitness relating to endurance and flexibility. Therefore, changing of daily life activity could be effective for adolescents without regular sports activity for a long time to improve base of physical fitness. In this regard, Gutin, et al., (2002, 2005) reported that while the duration of medium intensity activity is an improvement-related factor of cardiorespiratory physical fitness, the duration of high intensity activity was extracted as the stronger improvement-related factor. On the contrary, Kriemler, et al., (1999) indicated that although the higher intensity physical activity can be considerably effective in improving physical fitness, it is too strong for adolescents with less physical fitness and could inhibit physical activity on the next day. In light of these multiple findings, the intensity of physical activity, which is recommendable for adolescents is not uniform sufficiently. Therefore, it is necessary to consider the differences in the physical activity state, physical fitness level and body composition of adolescents, in order to maintain and improve health and fitness.

4.3. Physical Activity Status and Body Fat Percent

Keeping regular sports activity is expected to increase the energy expenditure accompanying physical activity, and intervention studies have revealed that it affects the fluctuation of %BF (Gutin, 2002; Deforche, et al., 2005; Lazzer, et al., 2005). Deforche, et al., (2005) emphasized the importance of exercise because the synergetic effect of weight-loss program combining exercise and diet restriction was found in their intervention study for obese children and adolescents. In contrast, although significant difference in physical fitness was observed due to the regular sports activity, significant difference in %BF was not seen in the cross-sectional research for high school students conducted by Angyan, et al., (2005). Moreover, Bar-Or and Baranowski (1994) also pointed that the volume of physical activity is not necessarily the determinant of obesity. Any significant correlation was not observed between physical activity and %BF in this study as well. The fact that not only the increase in energy expenditure accompanying physical activity but also energy balance adjustment by dietary management, would greatly affect %BF fluctuation is considered to be the reason of difference between the intervention study and the cross-sectional research. More specifically, it is supposed that the energy intake (EI) control in the intervention study as well as the exercise program might cause the fluctuation of body composition. In this study, when EI was determined from diet records of each group, the trained group was $4278\pm690kcal/day$ (margin of error with TEE: $-14\pm15\%$) and the untrained groups was $2469\pm488$ ($-10\pm11\%$), respectively in this study. It has been reported that the EI determined by the diet record method is less
than TEE (Rafamantanantsoa, 2003). Thus, it is not suitable for the evaluation of energy balance. However, it is assumed that both groups had sufficient dietary intake to fit TEE regardless of TEE size, because the weight fluctuation was not observed before or after the experiment period of this study. As a result, the relationship between each measured item of physical activity and %BF in both groups was not observed. This fact indicates the possibility that the element of physical activity alone tends not to greatly affect the fluctuation of body composition. Thus, when examining these study results, although it is not easy to come to a clear conclusion on the relationship between physical activity and body composition, the increase in energy expenditure accompanying physical activity may be effective to adjust the energy balance.

5. Limitation of this Study

Since there was considerable restriction in securing the number of subjects due to the application of DLW method and subjects were two polarized groups with great difference in physical activity status in this study, it requires special attention to generalize the study results. In addition, the measurement period using the accelerometer and the activity record was a total of three days including two weekdays and one holiday. In this regard, Trost, et al., (2000) reported that 5-9 days of measurement period is necessary to get highly reliable results in monitoring physical activity when subjects are 15 years of age. Therefore, it is undeniable that the three day period for measurement is possibly too short. Moreover, this study classified "sedentary" activity and "light" activity based on the accelerometer, referring in principle to "resting state in seated or supine position" and "from standing activity accompanying physical movement to slow walking", respectively. However, there still remain doubts as to how precisely the assessment was conducted based on these classifications. Therefore, in order to elucidate the findings of this study more specifically, a research study which has a sufficient number of subjects and a sufficient length should be conducted, and the discrimination of resting and low intensity physical activity should be clarified using the accelerometer. Furthermore, an intervention study would be required to clarify causal correlation. As far as is known to the author, a study which elucidates the difference in physical activity and physical fitness using the DLW method in conjunction with the accelerometer, has yet to be conducted. Thus, this study could contribute to future study as the basic material to establish a recommended intensity and times of physical activity in a day based on the energy expenditure and a standard value of energy requirement.

6. Conclusion

This study showed the differences in TEE, intensity and time of physical activity in a day due to regular sports activity (enrollment or non-enrollment to a sport club) in adolescents by using the DLW method, in conjunction with the accelerometer. In addition, this study investigated their influence of physical activity on physical fitness and %BF. The main findings of this study are as follows.

1) TEE and PAL of adolescents without regular sports activity are significantly low compared to those with regular sports activity. No sports activity has a great risk to cause an inactive life style activity such as standing and seated positions with less movement.

2) To maintain regular sports activity will increase PAL and duration of "light", "moderate" and "vigorous" activity, which is effective in improving endurance and flexibility in physical fitness.

3) It is possible that the fluctuation of %BF is not affected only by the increase of physical activity.

These results suggested that regular sports activity may be significant to maintain and promote health and fitness in adolescents.

References


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