Effect of long-term leisure time physical activity on lean mass and fat mass in girls during adolescence

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Völgyi E, Alén M, Xu L, Lyytikäinen A, Wang Q, Munukka E, Wiklund P, Tylavsky FA, Cheng S. Effect of long-term leisure time physical activity on lean mass and fat mass in adolescent girls. J Appl Physiol 110: 1211–1218, 2011. First published February 17, 2011; doi:10.1152/japplphysiol.00996.2010.—The purpose of this 7-yr prospective longitudinal study was to examine if the level and consistency of leisure-time physical activity (LTPA) during adolescence affected the quantity and distribution of lean mass (LM) and fat mass (FM) at early adulthood. The study subjects were 202 Finnish girls who were 10–13 yr old at baseline. LM and FM of the total body (TB), arms, legs, and trunk were assessed by dual-energy X-ray absorptiometry. Muscle cross-sectional area (mCSA) of the left leg was assessed by peripheral quantitative computed tomography. Scores of LTPA were obtained by questionnaire. Girls were divided into four groups comprising those with consistently low (G_{LH}) physical activity, or consistently high (G_{HH}) physical activity, or those whose physical activity changed from low to high (G_{HL}), or from high to low (G_{LH}), over the 7 yr of follow-up. At baseline, no differences were found in LM, FM, and FM% among the groups in any of the body segments. By the end of the study G_{HH} and G_{HL} had higher values of LM of the TB, arms, legs, and trunk than that of the G_{LH} and G_{LH} groups (P < 0.05, respectively). High FM% of the TB was associated with low level of LTPA, but no significant differences were found in the absolute amount of FM and mCSA among the LTPA groups. Our results suggest that a consistently high level of LTPA during the transition from prepuberty to early adulthood has a positive effect on lean mass gain in girls. Participating in 5 h of LTPA per week had a significant effect on FM% but not on the absolute amount of fat mass.

longitudinal; skeletal muscle mass; DXA

SKELETAL MUSCLE MASS and lean body mass have been reported to be important predictors of muscle strength and performance (39), balance (35) and postural control (5), bone mass (11, 17), insulin resistance (39), and obesity (39). Fat distribution also plays a specific role for heart diseases (18, 24), diabetes (34), and metabolic syndrome (38). As obesity fast becomes a global epidemic (27), it is increasingly important to understand the role of modifiable factors such as physical activity that may impact lean and fat mass during the first decades of life. It has been shown that habitual physical activity during puberty has a significant independent influence on lean body mass accrual in girls when the results are controlled for maturation and growth in longitudinal studies (1), but it does not have an influence on fat mass in girls (29). Cross-sectional studies (10) also showed that children with low physical activity level had higher fat mass percentage and that total physical activity was positively associated with the percentage of fat free mass. However, questions still remain unanswered concerning the specific levels and types of physical activity that are beneficial for body composition, and whether changes in the level of physical activity during puberty result in differences in lean and fat mass accrual by early adulthood.

Thus the purpose of this 7-yr prospective longitudinal study was to evaluate J) if girls with consistently high LTPA from prepuberty through to early adulthood experience benefits in terms of lean and fat mass accrual by early adulthood; 2) if increasing the level of LTPA from low to high from prepuberty throughout adolescence has beneficial effects on the quantity and distribution of lean and fat mass by early adulthood. We hypothesized that girls whose LTPA was either consistently high or increased during puberty would have greater LM at the age of 18 yr compared with those whose LTPA was either consistently low or decreased from age 11 to 18 yr.

MATERIALS AND METHODS

Study participants. The flow chart (Fig. 1) details the subjects and the study design that has been described fully in our earlier reports (6, 7). Briefly, the study subjects were first contacted via class teachers teaching grades 4 to 6 (age 9 to 13 yr) in 61 schools in the city of Jyväskylä and its surroundings in Central Finland (96% of all the schools in these areas). Of those eligible, 396 girls participated in the laboratory tests one to eight times over a maximum period of 8 yr (mean duration of total follow-up was 7.5 yr and mean age at last follow-up was 18.3 yr). Of the 396 girls, 258 girls participated in a calcium and vitamin D intervention trial during the first 2 years (6), and 235 participated in the 7-yr follow-up assessments (7). Of these, 101 girls were from the intervention group and 134 from the nonintervention group. Owing to missing physical activity questionnaires, 33 subjects were excluded from the final analysis. There was no intervention effect on body composition (6) (data not shown), thus the sample was pooled for these analyses.

We performed a comparison in body height, weight, BMI, Tanner stage, and physical activity scores between those girls who had bone assessments at 7-yr follow-up (n = 202) and the larger group of girls who just had initial assessments (n = 1,026–1,126) at the age of 11. Except for age and Tanner stage, no differences were found between the subset and the whole cohorts in menarche age, body height, weight, BMI, and physical activity scores. The age and Tanner stage differences arose from the fact that the subgroup was initially limited to age 10–12 yr and Tanner stage I-II, whereas in the larger cohort it was age 10–13 yr and Tanner stage I-III. Thus the subset sample was...
representative of the larger original target population in all mentioned variables.

The study protocol was approved by the ethical committee of the University of Jyväskylä, the Central Finland health care district, and the Finnish National Agency of Medicines. Informed consent was given by all subjects and their parents prior to the assessments.

Physical activity assessment. LTPA level was evaluated using a self-administered physical activity questionnaire, which was a modified version of a validated questionnaire used in a previous WHO study (16, 31). The modification consisted of two additional questions asking about the frequency and duration of physical exercise. Specifically, the questionnaire asked the girls what were the first, second, and third favorite physical activities they participated in outside of school, the duration of exercise in each session, and the number of sessions each week. This could include both sports and other more informal physical activities. The intensity of each activity was calculated on the basis of the energy expenditure per minute (25). Bone loading was based on whether the activity was weight bearing or not. We constructed a formula to calculate the LTPA score:

$$\text{LTPA Score} = \text{frequency} \times \sum_{1-3} \text{intensity index} \times \text{duration} \times \text{loading} = \text{non-weight bearing} = 1 \text{ and weight bearing} = 2.$$

The LTPA scores for the girls were validated against activity energy expenditure estimated from doubly-labeled water and indirect calorimetry ($n = 17$, $r = 0.651$, unpublished data).

To test if consistency or change of physical activity level during adolescence had significant effects on lean and fat mass gain, girls were divided first into two groups according to the median values of their LTPA scores at screening and at the 7 yr follow-up visit. Four activity groups were then formed as follows: consistently high ($G_{HH}$; $n = 50$), consistently low ($G_{LL}$; $n = 53$), changed from high to low ($G_{HL}$; $n = 47$), or low to high ($G_{LH}$; $n = 51$).

To test whether the differences already existed at baseline, a subgroup was formed comprising girls who had valid LTPA scores and body composition assessments both at baseline and follow-up ($G_{HI}; n = 26$, $G_{LI}; n = 31$, $G_{HI}; n = 12$, $G_{LH}; n = 16$).

Physical inactivity (PIA) was obtained from questionnaire and calculated as the sum of sitting and lying hours per day.

Diet. Dietary information was obtained from a food-intake diary kept for three successive days (2 weekdays, i.e., ordinary school days, and 1 weekend day) and is described elsewhere (8). For this report, total intakes of energy and energy yielding nutrients were analyzed.

Anthropometric measurements. All measurements were performed after overnight fasting (12 h). Participants were weighed with light clothes and without shoes. Height was determined using a fixed wall-scale measuring device to the nearest 0.1 cm. Weight was determined within 0.1 kg for each subject using an electronic scale, calibrated before each measurement session. BMI was calculated as weight (kg) per height (m)$^2$.

Dual-energy X-ray absorptiometry assessment. Dual-energy X-ray absorptiometry (DXA; Prodigy, GE Lunar, Madison, WI, with software version 9.3) was used to estimate lean tissue mass (LM) and fat mass (FM) of the total body (TB), legs, arms, and trunk. All metal items were removed from the participants to ensure the accuracy of the measurement. The subjects were positioned in the center of the table for each scan. They were scanned using the default scan mode automatically selected by the Prodigy software. Additional custom analysis was made for the android and gynoid part of the body. Three body regions (ROI1, ROI2, and ROI3) were measured from the total body scan images using bones as landmarks (see Fig.2). The coefficient of variation (CV%) of two repeated measurements on the same day was on average 1.0% for LM, and 2.2% for FM in this study.

Peripheral quantitative computed tomography assessment. A peripheral quantitative computed tomography device (XCT-2000, Stratec Medizintechnik, Pforzheim, Germany) was used to scan left tibia (37, 42). A 2-mm-thick single tomographic slice was scanned.
Fig. 2. Custom analysis of android and gynoid fat mass, lean mass, and fat mass percentage. ROI1 (top box; no. 1) is defined as the area between the lowest rib and top of the pelvis. ROI2 (middle box; no. 2) is defined as the area between the top of the pelvis and the top of the greater trochanter of femur. ROI3 (bottom box; no. 3) is defined as the area between the top of the greater trochanter of femur and the bottom of the genital.

The subcutaneous adipose tissue before analysis. The threshold for muscle was 10–279 mg/cm³. The CV% was 1% for the mCSA.

Statistical analysis. Data were checked for normality by Shapiro-Wilk’s W test and for homogeneity by Levene’s test before each analysis. ANOVA with Tukey’s post hoc test or Kruskal-Wallis ANOVA with Mann-Whitney test was used to test the differences among the LTPA groups at the baseline, and analysis of covariance (ANCOVA) was used at follow-up. Frequency distribution of the weight-bearing and non weight-bearing exercises at baseline and follow-up was tested by $\chi^2$ test in each LTPA group. Statistica for Windows v8.0 software (StatSoft, Tulsa, OK) was used to perform the statistical analyses. A $P$ value of $<0.05$ was considered statistically significant.

RESULTS

The most common summer LTPA were swimming (38%), cycling (26%), and horseback riding (23%) at age 11, and cycling (35%), walking (21%), and jogging (11%) at age 18. The amount of weight-bearing exercise increased for those in the GHH, GLH, and GHL groups at age 18 ($P < 0.001$, respectively, by $\chi^2$ test). The GLL also increased the amount of weight-bearing exercise at the follow-up ($P < 0.001$ by $\chi^2$ test), but had still a preponderance of nonloading physical activities (63%). There were differences in times per week and hours per week among the LTPA groups ($P < 0.001$, Kruskal-Wallis ANOVA). The most frequent answers for the LTPA were once for a total of 2.5 h of the girls in the GHH and GLL groups, while 5 times and 5 h/wk in the GHL and GLH groups at age 18. There were no differences in total energy intake and weight adjusted carbohydrate, fat, and protein intake among the LTPA groups.

The physical characteristics of the girls at age 18 in different LTPA groups during puberty are presented in Table 1. Briefly, there were no differences in age, body height, body weight, BMI, menarche age, and in physical inactivity hours among the LTPA groups.

Table 2 shows the comparison of body composition among the groups. The GHH and GLL had higher values of LM of the TB, arms, legs, and trunk than that of the GHL and GLH ($P < 0.001$, respectively) at age 18. There were no significant differences in mCSA, and amount of FM. There were significant differences in FM% at the total body, ROI1 (upper abdominal area), and ROI3 (gynoid area) but no differences in post hoc
Lean Mass, kg girls. Kriemler and colleagues (20) found that a one-school- LM at different body segments during puberty in ordinary focusing on the longitudinal effect of LTPA on both FM and (20, 29, 36). To our knowledge there is no longitudinal study focus on bone accrual (3, 12, 22, 40) or changes in fat mass positive effect on FM% at the age 18. At the same time, LTPA during puberty had no significant effect body. Girls who changed their LTPA from low to high during DISCUSSION
detect the differences among the LTPA groups. comparisons were found, although there was 91% power to
detect the differences among the LTPA groups. The percentage differences between the G11 group and other
groups are given in Figs. 3 and 4. The GHH and G11 groups show
similar results in all measured variables except for the ROI2 LM.
To verify whether the differences in LM and FM variables
found after 7-yr follow-up already existed at baseline, we
compared those who had body composition assessments at
both age 11 and 18 (Table 3). No differences were found in
age, body height, body weight, BMI, physical inactivity
hours, total energy intake, and energy adjusted carbohydrate, fat, and protein intake among the LTPA groups. No
significant differences were found in any of the measured
variables in LM, FM, FM%, and mCSA among the LTPA
groups at baseline.

TABLE 2. Body composition of the girls at 84 mo follow-up according to consistency of LTPA during puberty

<table>
<thead>
<tr>
<th></th>
<th>High-High (n = 50)</th>
<th>High-Low (n = 47)</th>
<th>Low-High (n = 51)</th>
<th>Low-Low (n = 53)</th>
<th>ANCOVA*</th>
<th>Post Hoc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HH-HL</td>
</tr>
<tr>
<td>Lean Mass, kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HH-LH</td>
</tr>
<tr>
<td>Total body</td>
<td>38.8 ± 0.40</td>
<td>37.0 ± 0.42</td>
<td>39.1 ± 0.41</td>
<td>36.8 ± 0.39</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Arms</td>
<td>3.81 ± 0.07</td>
<td>3.64 ± 0.07</td>
<td>3.93 ± 0.07</td>
<td>3.54 ± 0.06</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Legs</td>
<td>13.4 ± 0.18</td>
<td>12.6 ± 0.18</td>
<td>13.5 ± 0.18</td>
<td>12.5 ± 0.17</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Trunk</td>
<td>18.4 ± 0.20</td>
<td>17.6 ± 0.21</td>
<td>18.6 ± 0.20</td>
<td>17.7 ± 0.19</td>
<td>0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HH-LL</td>
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<tr>
<td>Fat Mass, kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HL-HL</td>
</tr>
<tr>
<td>Total Body</td>
<td>18.2 ± 0.93</td>
<td>20.1 ± 0.98</td>
<td>18.0 ± 0.96</td>
<td>19.1 ± 0.91</td>
<td>0.475</td>
<td>NS</td>
</tr>
<tr>
<td>Arms</td>
<td>1.71 ± 0.10</td>
<td>1.94 ± 0.11</td>
<td>1.67 ± 0.10</td>
<td>1.73 ± 0.10</td>
<td>0.309</td>
<td>NS</td>
</tr>
<tr>
<td>Legs</td>
<td>7.40 ± 0.32</td>
<td>8.23 ± 0.34</td>
<td>7.50 ± 0.33</td>
<td>8.02 ± 0.31</td>
<td>0.327</td>
<td>NS</td>
</tr>
<tr>
<td>Trunk</td>
<td>8.45 ± 0.52</td>
<td>9.24 ± 0.55</td>
<td>8.23 ± 0.54</td>
<td>8.72 ± 0.51</td>
<td>0.629</td>
<td>NS</td>
</tr>
<tr>
<td>Android</td>
<td>1.35 ± 0.00</td>
<td>1.52 ± 0.09</td>
<td>1.31 ± 0.09</td>
<td>1.43 ± 0.09</td>
<td>0.455</td>
<td>NS</td>
</tr>
<tr>
<td>Glycogen</td>
<td>4.04 ± 0.15</td>
<td>4.34 ± 0.16</td>
<td>4.04 ± 0.16</td>
<td>4.25 ± 0.15</td>
<td>0.522</td>
<td>NS</td>
</tr>
<tr>
<td>ROI1</td>
<td>1.40 ± 0.11</td>
<td>1.49 ± 0.11</td>
<td>1.33 ± 0.11</td>
<td>1.44 ± 0.11</td>
<td>0.790</td>
<td>NS</td>
</tr>
<tr>
<td>ROI2</td>
<td>2.69 ± 0.16</td>
<td>2.85 ± 0.17</td>
<td>2.69 ± 0.17</td>
<td>2.78 ± 0.11</td>
<td>0.878</td>
<td>NS</td>
</tr>
<tr>
<td>ROI3</td>
<td>2.16 ± 0.10</td>
<td>2.29 ± 0.10</td>
<td>2.09 ± 0.10</td>
<td>2.30 ± 0.09</td>
<td>0.489</td>
<td>NS</td>
</tr>
<tr>
<td>Fat Mass Percent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HL-LL</td>
</tr>
<tr>
<td>Total Body</td>
<td>29.9 ± 1.01</td>
<td>33.1 ± 1.03</td>
<td>29.5 ± 1.03</td>
<td>32.4 ± 0.97</td>
<td>0.040</td>
<td>NS</td>
</tr>
<tr>
<td>ROI1</td>
<td>33.7 ± 1.43</td>
<td>38.6 ± 1.37</td>
<td>33.7 ± 1.37</td>
<td>38.1 ± 1.29</td>
<td>0.016</td>
<td>NS</td>
</tr>
<tr>
<td>ROI2</td>
<td>36.1 ± 1.38</td>
<td>38.7 ± 1.41</td>
<td>35.4 ± 1.4</td>
<td>38.0 ± 1.33</td>
<td>0.376</td>
<td>NS</td>
</tr>
<tr>
<td>ROI3</td>
<td>41.0 ± 0.96</td>
<td>43.8 ± 0.98</td>
<td>40.6 ± 0.97</td>
<td>43.7 ± 0.92</td>
<td>0.041</td>
<td>NS</td>
</tr>
<tr>
<td>Tibial Shaft</td>
<td>mCSA (mm²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>4.64 ± 0.14</td>
<td>6.14 ± 0.15</td>
<td>6.55 ± 0.15</td>
<td>6.20 ± 0.14</td>
<td>0.200</td>
<td>NS</td>
</tr>
</tbody>
</table>

Values are given as original group means ± SE. *Covariate: body height at 7-yr follow-up.

year-long physical activity program could decelerate the BMI
gain and skinfold thickness in 7- and 11-yr-old children. Others
could not see a positive effect of physical activity on FM in
children (30) or in girls (29), but have speculated that there
may be a certain threshold level of physical activity in female adolescents below which effects on FM are not observed. Our
overall analysis showed that there was no significant difference
in amount of FM but there was difference in FM% among the
LTPA groups, although the differences could not be localized
between any two specific groups.

Few cross-sectional studies have concentrated on the effect
of PA on LM. Tobias and colleagues (36) described how LM
was positively related to physical activity in 11-year-old children.
In a longitudinal design, Baxter-Jones and colleagues (1)
reported that habitual physical activity had a significant, inde-
dependent effect on LM accrual during adolescence. Parizkova
(30) found that boys who regularly trained between age 11 and
18 increased their FFM more, while FM remained minimal. Our study was focused on LTPA not high-demand competitive
sports. Although our results did not reveal significant differ-
ences in FM, we did see differences in FM% among the LTPA
groups. Participating in long-term LTPA for 5 times/wk and 5
h/wk during puberty was not enough to prevent absolute fat
accumulation but did have some effect on FM%. Hence the
main beneficial effect is on LM accrual. According to a recent
report from 2008 (15), 72% of Finnish females (age between
15 and 24) practice physical exercise in their leisure time at
least 2–3 times/wk. In our sample, the GHH group participated
in the GHH was indeed a highly active group, while GLL was a
least 2–3 times/wk. In our sample, the GHH group participated

In the present study we found that girls with consistently higher
LTPA than their peers from the age 11 to 18 had significantly
higher LM at various sites, including arms, legs, trunk, and total
body. Girls who changed their LTPA from low to high during puberty also had significantly higher LM at the age of 18 com-
pared with those who stayed at low level or decreased their LTPA.
At the same time, LTPA during puberty had no significant effect
on the absolute amount and distribution of fat mass, but had a
positive effect on FM% at the age 18.

Most previous studies investigating the effect of exercise focus on bone accrual (3, 12, 22, 40) or changes in fat mass
(20, 29, 36). To our knowledge there is no longitudinal study focusing on the longitudinal effect of LTPA on both FM and
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low activity, but not exclusively inactive group, with reference to the Finnish population.

The intensity and type of exercise is crucial to maintain or decrease FM. In a recent study, Lusk and colleagues (23) concluded that at least 30 min cycling or brisk walking compared with slow walking per day was associated with less weight gain in overweight and obese premenopausal women. In our study, cycling and walking were the two most common exercises for the girls at age 18, which indicate that the same type of exercises may result in different outcomes in different age groups, although it is still beneficial for the body composition.

Skeletal muscle plays an important role in locomotion, and it is also important for both the prevention and the management of a variety of diseases (26). It is the largest tissue mass in the human body. Because of its mass, it plays a major contributor in thermogenesis and therefore to the basal metabolic rate. It plays an important role in lipid oxidation addition due to the large number of mitochondria and it maintains the balance in lipoprotein and triglyceride homeostasis (33). Hence, maintaining skeletal muscle mass through active use is one key aspect to health.

Quantifying the regional fat distribution can be used as an early sign for predicting the health risks in later life (4). He and colleagues (14) found among children from different races that late pubertal girls were not consistently different in fat distribution from prepubertal girls who already showed an adult female pattern. Goulding et al. (13) concluded that girls accumulate a higher proportion of their total body FM than lean tissue mass during puberty and their fat distribution becomes more android and less gynoid with maturity. Unfortunately these studies lack information about physical activity. In our study we did not find differences in the absolute amount of FM, but we did find differences in FM% of the total body and in both the upper android and gynoid body regions among the LTPA groups. Those girls who continuously had a high level of LTPA or increased their leisure time exercise level during puberty had a significantly greater amount of LM and appeared to have significantly lesser amount of FM% in the total body and both the upper android and gynoid body regions of the body than GLL and GHL. Explanation of this result is difficult since most of the organs in the human body are located in the abdominal area (ROI1), while the pelvic area (ROI2) contains mainly bone components, where DXA has to estimate LM and FM over bone. Therefore, the validity of the results at the abdominal and pelvic area is questionable, but it does potentially give important information about the effect of physical activity on those regions also.

Fig. 3. Comparison of the percentage differences in fat mass and lean mass (FM, left; LM, right) between the consistently low exercising girls (GLL) and other groups at age of 18. The vertical line (0) represents the GLL group. Horizontal lines, 95% confidence interval; •, mean differences from the GLL.
Long-term LTPA Effect on Lean Mass and Fat Mass

Table 3. Basic characteristics and body composition of the girls (who also have the follow-up data) at baseline according to consistency of LTPA

<table>
<thead>
<tr>
<th></th>
<th>High-High (n = 26)</th>
<th>High-Low (n = 16)</th>
<th>Low-High (n = 16)</th>
<th>Low-Low (n = 31)</th>
<th>ANOVA P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, yr</strong></td>
<td>11.2 ± 0.6</td>
<td>11.3 ± 0.8</td>
<td>11.5 ± 0.9</td>
<td>11.2 ± 0.7</td>
<td>0.700</td>
</tr>
<tr>
<td><strong>Height, cm</strong></td>
<td>146 ± 7.2</td>
<td>144 ± 7.7</td>
<td>147 ± 7.9</td>
<td>145 ± 7.8</td>
<td>0.543</td>
</tr>
<tr>
<td><strong>Weight, kg</strong></td>
<td>39.5 ± 8.7</td>
<td>36.7 ± 9.3</td>
<td>37.6 ± 6.3</td>
<td>37.7 ± 7.3</td>
<td>0.775</td>
</tr>
<tr>
<td><strong>BMI, kg/m²</strong></td>
<td>18.3 ± 2.8</td>
<td>17.6 ± 3.7</td>
<td>17.2 ± 1.8</td>
<td>17.9 ± 2.3</td>
<td>0.482</td>
</tr>
<tr>
<td><strong>Menarche age, yr</strong></td>
<td>13.6 ± 1.1</td>
<td>13.3 ± 0.9</td>
<td>13.6 ± 1.2</td>
<td>13.3 ± 0.9</td>
<td>0.628</td>
</tr>
<tr>
<td><strong>LTPA score</strong></td>
<td>91 ± 52</td>
<td>100 ± 68</td>
<td>18 ± 8</td>
<td>16 ± 9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Inactivity, h/day</strong></td>
<td>18.1 ± 2.5</td>
<td>19.5 ± 1.8</td>
<td>17.5 ± 1.6</td>
<td>18.7 ± 1.9</td>
<td>0.278</td>
</tr>
<tr>
<td><strong>Energy, kcal/day</strong></td>
<td>1570 ± 391</td>
<td>1714 ± 266</td>
<td>1555 ± 276</td>
<td>1610 ± 402</td>
<td>0.325</td>
</tr>
<tr>
<td><strong>CH, %Energy</strong></td>
<td>52.1 ± 6.7</td>
<td>55.5 ± 4.6</td>
<td>54 ± 5.5</td>
<td>53.4 ± 6.7</td>
<td>0.455</td>
</tr>
<tr>
<td><strong>Fat, %Energy</strong></td>
<td>32 ± 5.5</td>
<td>31.1 ± 4.1</td>
<td>30.7 ± 4.2</td>
<td>31.3 ± 6.1</td>
<td>0.884</td>
</tr>
<tr>
<td><strong>Protein, %Energy</strong></td>
<td>15.9 ± 3.3</td>
<td>13.3 ± 2.8</td>
<td>15.2 ± 2.4</td>
<td>15.2 ± 3.1</td>
<td>0.112</td>
</tr>
<tr>
<td><strong>DXA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lean Mass, kg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total body</td>
<td>27.14 ± 0.61</td>
<td>26.06 ± 1.37</td>
<td>26.75 ± 0.98</td>
<td>26.17 ± 0.71</td>
<td>0.761</td>
</tr>
<tr>
<td>Arms</td>
<td>2.50 ± 0.07</td>
<td>2.29 ± 0.14</td>
<td>2.39 ± 0.10</td>
<td>2.34 ± 0.08</td>
<td>0.394</td>
</tr>
<tr>
<td>Legs</td>
<td>9.20 ± 0.23</td>
<td>8.69 ± 0.50</td>
<td>9.09 ± 0.41</td>
<td>8.68 ± 0.28</td>
<td>0.529</td>
</tr>
<tr>
<td>Trunk</td>
<td>12.63 ± 0.32</td>
<td>12.24 ± 0.69</td>
<td>12.42 ± 0.46</td>
<td>12.31 ± 0.34</td>
<td>0.908</td>
</tr>
<tr>
<td>Android</td>
<td>1.58 ± 0.05</td>
<td>1.54 ± 0.10</td>
<td>1.56 ± 0.07</td>
<td>1.54 ± 0.05</td>
<td>0.967</td>
</tr>
<tr>
<td>Gynoid</td>
<td>3.45 ± 0.12</td>
<td>3.30 ± 0.22</td>
<td>3.40 ± 0.16</td>
<td>3.29 ± 0.11</td>
<td>0.779</td>
</tr>
<tr>
<td>ROI1</td>
<td>1.65 ± 0.08</td>
<td>1.73 ± 0.16</td>
<td>2.03 ± 0.31</td>
<td>1.65 ± 0.09</td>
<td>0.536</td>
</tr>
<tr>
<td>ROI2</td>
<td>2.96 ± 0.10</td>
<td>2.76 ± 0.18</td>
<td>2.90 ± 0.16</td>
<td>2.80 ± 0.12</td>
<td>0.713</td>
</tr>
<tr>
<td>ROI3</td>
<td>2.05 ± 0.07</td>
<td>2.01 ± 0.12</td>
<td>2.00 ± 0.09</td>
<td>2.03 ± 0.07</td>
<td>0.986</td>
</tr>
<tr>
<td><strong>Fat Mass, kg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total body</td>
<td>10.66 ± 1.18</td>
<td>9.04 ± 1.72</td>
<td>9.03 ± 1.01</td>
<td>9.89 ± 0.79</td>
<td>0.572</td>
</tr>
<tr>
<td>Arms</td>
<td>1.01 ± 0.14</td>
<td>0.76 ± 0.16</td>
<td>0.79 ± 0.1</td>
<td>0.86 ± 0.08</td>
<td>0.477</td>
</tr>
<tr>
<td>Legs</td>
<td>4.73 ± 0.45</td>
<td>3.88 ± 0.51</td>
<td>4.10 ± 0.39</td>
<td>4.40 ± 0.30</td>
<td>0.596</td>
</tr>
<tr>
<td>Trunk</td>
<td>4.38 ± 0.58</td>
<td>3.90 ± 1.01</td>
<td>3.63 ± 0.51</td>
<td>4.08 ± 0.42</td>
<td>0.600</td>
</tr>
<tr>
<td>Android</td>
<td>0.77 ± 0.12</td>
<td>0.66 ± 0.19</td>
<td>0.66 ± 0.09</td>
<td>0.68 ± 0.07</td>
<td>0.549</td>
</tr>
<tr>
<td>Gynoid</td>
<td>2.38 ± 0.22</td>
<td>2.06 ± 0.26</td>
<td>2.11 ± 0.18</td>
<td>2.23 ± 0.14</td>
<td>0.756</td>
</tr>
<tr>
<td>ROI1</td>
<td>0.79 ± 0.12</td>
<td>0.74 ± 0.25</td>
<td>0.67 ± 0.1</td>
<td>0.72 ± 0.08</td>
<td>0.562</td>
</tr>
<tr>
<td>ROI2</td>
<td>1.42 ± 0.17</td>
<td>1.18 ± 0.26</td>
<td>1.19 ± 0.15</td>
<td>1.29 ± 0.11</td>
<td>0.475</td>
</tr>
<tr>
<td>ROI3</td>
<td>1.27 ± 0.11</td>
<td>1.21 ± 0.16</td>
<td>1.16 ± 0.1</td>
<td>1.34 ± 0.1</td>
<td>0.711</td>
</tr>
<tr>
<td><strong>Fat Mass Percent</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Body</td>
<td>24.9 ± 1.8</td>
<td>22.6 ± 2.4</td>
<td>23.5 ± 1.9</td>
<td>25.0 ± 1.4</td>
<td>0.522</td>
</tr>
<tr>
<td>ROI1</td>
<td>29.3 ± 2.3</td>
<td>25.6 ± 3.6</td>
<td>26.4 ± 2.8</td>
<td>28.8 ± 1.8</td>
<td>0.552</td>
</tr>
<tr>
<td>ROI2</td>
<td>30.2 ± 2.1</td>
<td>27.4 ± 3.1</td>
<td>27.9 ± 2.7</td>
<td>30.2 ± 1.9</td>
<td>0.629</td>
</tr>
<tr>
<td>ROI3</td>
<td>37.8 ± 1.5</td>
<td>36.3 ± 2.1</td>
<td>35.9 ± 1.8</td>
<td>38.3 ± 1.3</td>
<td>0.714</td>
</tr>
<tr>
<td><strong>pQCT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tibial shaft</td>
<td>4.40 ± 0.15</td>
<td>4.17 ± 0.29</td>
<td>3.95 ± 0.16</td>
<td>4.07 ± 0.12</td>
<td>0.230</td>
</tr>
</tbody>
</table>

Values are means ± SD.

The limitations of our study include the use of a questionnaire to assess LTPA. While questionnaires have been reported to be the most feasible methods to estimate PA in large populations (28), over-reporting of PA by questionnaires (19) means they may not reflect the actual level of PA. Accelerometers or heart rate monitors may provide more accurate estimates of PA, but for a follow-up of several years these methods were not feasible in our study. Our own study (7) and a recent study of Kurtze and colleagues (21) showed that a PA questionnaire can be reproducible and provide useful measure of LTPA. In Finland, winter time physical activity is dominant and the LTPA scores are higher than that reported for the summer. Second, the lack of difference in FM and FM% could be due to increased error in measurement or sample size.

The proportion of overweight/obese girls was 12.4% in our sample (aged 16.5–20 yr in 202 girls), which is very similar to the figure of 13% quoted for Finnish girls aged 15–24 yr in a recent national report (15). This same national report found that, for the Middle Finland region, 23% of the girls have BMI over 25 kg/m² (15). Unfortunately the national report did not segregate statistics by overweight and obese. In our group, four (1.7%) out of 235 girls were classified as obese according to references Cole et al. (9) and WHO (41). This is in agreement with a recent report by Saari et al. (32), where the prevalence of obese girls was 1.8%. The reason for only one obese girl (by BMI) was due to the fact that the other three did not return their PA questionnaire. Those who did not return the questionnaire were heavier (64 vs. 60 kg) and had higher BMI (23.0 vs. 21.7 kg/m²) but no significant differences were found compared with those who returned the questionnaire in age, peak height velocity, age at menarche, body height, body weight, BMI, muscle performance, and body composition.

In conclusion, our results indicate that long-term consistently high levels of LTPA from age 11 to 18 have a positive
effect on LM and FM% in Finnish girls at the age of 18. Increasing LTPA from a low level during puberty to a high level at early adulthood promotes LM gain. Participating in 5 h of LTPA/wk had no significant effect on the absolute amount of FM, but did influence FM%. Encouraging girls to undertake LTPA regularly during the postmenarcheal years is important for body composition in terms of LM accrual in particular, but also to prevent excess relative FM gain. (Fig. 4)

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GRANTS

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DISCLOSURES

The study sponsors played no role in the design, methods, data management, or analysis, nor in the decision to publish. None of the authors have financial or personal interest affiliations with the sponsors of this research effort.

REFERENCES


