MODERATE PHYSICAL ACTIVITY CORRELATES WITH ELEVATED LEPTIN IN PHYSICALLY ACTIVE 10–12-YEAR-OLD BOYS WITH NORMAL BMI

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MODERATE PHYSICAL ACTIVITY CORRELATES WITH ELEVATED LEPTIN IN PHYSICALLY ACTIVE 10–12-YEAR-OLD BOYS WITH NORMAL BMI[1, 2]

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Summary.—The aim of this study is to examine the relations between physical activity of differing intensity and duration with body energy-balance hormone leptin in 10–12-year-old boys (N = 94) who participated in moderate-to-vigorous physical activity at least four to five times per week. The boys reported their physical activity using a questionnaire. They had normal body mass index (BMI, kg/m^2), and were at Tanner Stage 2 of development. Boys were divided into three subgroups by leptin levels: normal serum leptin (M ± .5 SD, n = 44, 1.2–3.9 ng/ml), low leptin (≤ M – .5 SD; n = 31, < 1.2 ng/ml), and high leptin (≥M + .5 SD; n = 19, > 3.9 ng/ml). There were significant differences between subgroups in anthropometric parameters and serum leptin levels, but not in physical activity. A significant correlation was found between leptin and moderate physical activity of at least five times per week for at least 30 minutes each time in the high leptin group (r = .61). In conclusion, the correlations between physical activity and leptin are weak; only moderate physical activity was correlated with leptin levels in the high leptin group.

Leptin is a multifunctional hormone that is secreted mostly from the white adipose tissue (Zhang, Proenca, Maffei, Barone, Leopold, & Friedman, 1994). The discovery of leptin changed opinion on adipose tissue's role in the regulation of energy balance. Serum leptin levels serve as an adiposity sensor to protect against starvation, and correlate with the extent of obesity; thus, leptin probably has a permissive role in high-energy metabolic processes, such as puberty (Weiss, Bremer, & Lustig, 2013). Serum leptin correlates highly with body mass index (BMI; kg/m^2) (Roemmich, Clark, Berr, Mai, Mantzoros, Flier, *et al.*, 1998). There is significant interindividual variation of fasting leptin levels for persons of similar age, BMI, and physical activity (Ruhl & Everhart, 2001), and interactions of

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genetic, dietary, environmental, and behavioural factors control leptin levels (Torjman, 2001).

Several studies have investigated the interactions between physical activity and leptin in obese children (Barbeau, Gutin, Litaker, Ramsey, Cannady, Allison, *et al.*, 2003; Martinez-Gomez, Eisenmann, Gomez-Martinez, Veses, Romeo, Veiga, *et al.*, 2012). As a rule, different physical activity programmes (several weeks or months) decreased body-fat tissue mass and leptin levels (Barbeau, *et al.*, 2003). Healthy children are recommended to undertake 30 to 60 minutes of moderate-to-vigorous physical activity (MVPA) each day (Pate & O'Neill, 2012). As a rule, this consists of mandatory school physical education lessons and extra-curricular school-organised sport activities. The effect of physical activity on leptin might be modulated by the sympathoadrenal system, which has a significant function in energy balance (Nonogaki, 2000).

Several studies have assessed the relationships between physical activity and leptin in non-obese peripubertal boys, but found conflicting results. Martinez-Gomez, *et al.* (2012) showed that vigorous physical activity (as measured by accelerometer) showed a significant inverse correlation with leptin in 13- to 14-year-olds. Negative (Romon, Lafay, Bresson, Oppert, Borys, Kettaneh, *et al.*, 2004), positive (Salbe, Nicolson, & Ravussin, 1997), or no significant correlations (Platat, Wagner, Klumpp, Schweitzer, & Simon, 2006; Metcalf, Jeffery, Hosking, Voss, Sattar, & Wilkin, 2009) with physical activity have all been ascribed to leptin among previous studies of young people, each of which examined physical activity using questionnaires. There is no information available about whether leptin levels are associated with moderate or vigorous exercise in non-obese 10- to 12-year-old boys of the same biological maturity. This information (especially high leptin, normal BMI) will be useful in developing a better understanding of the development of obesity and its metabolic risk in peripubertal boys.

The aim of this study is to examine the relationships between physical activity of differing intensity and duration to serum leptin levels in physically active 10–12-year old boys with normal BMI and who are at Tanner Stage 2. Tanner Stage 2 (typical for 10–12 year old boys) was selected because leptin levels during puberty have been shown to reach the highest level by Tanner Stage 2 (Roemmich, *et al.*, 1998). In total the boys had four to five MVPA per week (recommendation is to exercise MVPA every day at least 30 to 60 minutes per day (Pate & O'Neill, 2012).

Hypothesis: Serum leptin will be significantly correlated with physical activity in boys with normal BMI at Tanner Stage 2 who take part in obligatory physical education lessons (mostly MVPA) and additionally with organised extra-curricular sport activities (MVPA) at least two times per week.

Method

Participants

In total, 94 healthy Caucasian boys ages 10 to 12 years participated in the study. The boys were from schools in the city and surroundings of Tartu, Estonia. The study is a part of a larger longitudinal study investigating anthropometry, body composition, bone mineral density, peak O_2 consumption, physical activity, and several hormones in the blood during development in puberty. Participants were selected from a wider pool of 374 boys who participated during the first year of a wider study, from which the sample was selected based on the following entry criteria: (1) normal BMI per Cole, Bellizzi, Flegal, & Dietz (2000), (2) regular participation in obligatory physical education lessons at school two to three times per week, as well as additional participation in organised extra-curricular sport activities for competitive purposes (sport schools, sport clubs, etc.) at least two times per week, and (3) Tanner pubertal Stage 2 (beginning of peripuberty), a self-assessment with an illustrated questionnaire evaluating pubic hair (Tanner, 1962). The boys did not change their eating habits and were not taking any medications. As in a similar condition (normal BMI, physical activity level, Tanner stage) the leptin levels were relatively different. In connection with that, the boys were divided into three subgroups by leptin level: normal serum leptin ($M \pm .5\ SD$, $n = 44$, 1.2–3.9 ng/ml), low leptin ($\leq M - .5\ SD$; $n = 31$, < 1.2 ng/ml), and high leptin ($\geq M + .5\ SD$; $n = 19$, > 3.9 ng/ml). This study was approved by the Medical Ethics Committee of the University of Tartu (Estonia). All parents and children were informed of the purposes and contents of the study, written informed consent was obtained from the parents before participation, and the children gave verbal consent.

Measures

Body height was measured to the nearest 0.1 cm using a Martin metal anthropometer. Body mass was measured with minimal closing with medical scale (A&D Instruments, UK, to the nearest .05 kg). BMI was calculated as the body mass (kg) divided by the square of body height (m^2).

Boys reported their physical activity using a questionnaire from the Estonian Children's Personality, Behaviour, and Health Study (ECPBHS) (Harro, Eensoo, Kiive, Merenäkk, Alep, Oreland, *et al.*, 2001) with minor adaptation (Lakka, Venäläinen, Rauramaa, Salonen, Tuomilehto, & Salonen, 1994; Kowalski, Crocker & Faulkner, 1997). The modified version of the questionnaire consists of eight questions about physical activity (Table 2); only the questions which directly connected with the aims of the study were administered.

To measure leptin levels, blood samples were obtained after an overnight fast (confirmed by both parent and boys) from the antecubital vein

with the participant in the sitting position between 8:00 and 9:00 a.m. The blood serum was separated and frozen at –80°C for later analyses. Leptin concentration was determined by ELISA sandwich method using a kit from Mediagnost GmbH, Rottingen, Germany. The inter- and intra-assay CVs were less than 10%.

Analyses

All statistical analyses were run using the SPSS (Version 14.0 for Windows, SPSS Inc., Chicago, USA). Descriptive statistics were calculated and differences between subgroups were analysed using ANOVA (LSD *post hoc*). Partial correlations, controlling for BMI and body mass, were used to assess relations between leptin concentration and physical activity. The level of significance was set at $p < .05$ for all statistical analyses.

Results

Mean anthropometrical parameters and leptin levels are presented in Table 1. There were no statistically significant differences between groups in mean age. Body height was the highest in the high leptin group, compared with the low leptin group ($p < .05$). Body mass, BMI, and leptin levels were significantly different between all three subgroups (Table 1).

TABLE 1
Anthropometric Parameters and Leptin Concentration in Boys

Group	Total Group ($n = 94$)		Low Leptin Group ($n = 31$)		Normal Leptin Group ($n = 44$)		High Leptin Group ($n = 19$)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age, yr.	11.2	0.7	11.0	0.7	11.3	0.7	11.1	.6
Body height, m	1.47	0.71	1.46	0.82	1.48	0.63	1.50†	.80
Body mass, kg	37.5	5.3	34.9	4.7	37.4*	4.5	42.1*†	5.4
BMI, kg/m^2	17.2	1.5	16.4	1.1	17.1*	1.3	18.7*†	1.5
Leptin, ng/ml	3.08	2.76	0.86	0.43	2.75*	0.81	7.47*†	2.89

Note.—*Significantly different from the low leptin group, $p < .05$. †Significantly different from the normal leptin group, $p < .05$.

Physical activity levels are presented in Table 2. There were no significant differences between the three groups. Serum leptin levels were correlated to various measures of physical activity; most comparisons were not significant. In the high leptin group only, serum leptin was correlated with moderate physical activity at least five times per week (each session at least 30 min, $r = .61$, $p < .001$).

Discussion

Overall, the results did not support the hypothesis that leptin levels correlate with physical activity in this population, 10- to 12-year-old boys

TABLE 2
PHYSICAL ACTIVITY PARAMETERS IN BOYS

Question	Total Group (n = 94)		Low Leptin Group (n = 31)		Normal Leptin Group (n = 44)		High Leptin Group (n = 19)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
How many days last week were you physically active at least 30 minutes per day (0–7)	4.0	1.4	4.2	1.4	3.9	1.5	3.9	1.2
Participation in official PE lessons in school last academic year (1–5)	4.5	.5	4.5	.5	4.4	.5	4.6	.5
How many months in the last year did you take part in outside school sport sessions in sport schools, sport clubs, etc. (0–12)	8.8	2.9	8.1	3.1	8.9	2.9	9.4	2.7
How many times per week did you take part in organised sport sessions (0–7)	3.0	1.0	3.0	.9	3.1	1.2	3.1	.9
What was the duration of one organised sport session (min.)	78.5	22.3	76.0	17.7	77.5	20.9	85.0	30.7
How frequently were you active outside school near your home while playing with friends, etc. (times per week) (0–4)	1.9	.7	1.8	.7	1.9	.8	1.9	.6
Was your moderate physical activity last week equal to or higher than at least 30 minute sessions 5 times per week (1–yes, 2–no)	1.4 yes 56, no 38	.5	1.4 yes 19, no 12	.5	1.4 yes 25, no 19	.5	1.3 yes 12, no 7	.5
Was your vigorous physical activity last week equal to or higher than at least 30 minute sessions 3 times per week (1–yes, 2–no)	1.1 yes 78, no 16	.3	1.1 yes 27, no 4	.3	1.2 yes 36, no 8	.4	1.1 yes 15, no 4	.3

with normal BMI, Tanner Stage 2 puberty, who participated in moderate-to-vigorous physical activity for a total of four to five times per week. However, in the high leptin group, only regular moderate exercise at least five times per week, with at least a 30-min. session each time, was associated with leptin levels.

There was no significant correlation between leptin and participation in organised sport outside of school. Previously, it is known that only moderate-to-vigorous physical activity (MVPA) was correlated with serum leptin levels in 13- to 17-year-old adolescents (Martinez-Gomez, *et al.*, 2012) and a mixed group of 8- to 11-year-old girls with obesity or normal body mass (Belcher, Chou, Nguyen-Rodriguez, Hsu, Byrd-Williams, McClain, *et al.*, 2013). The current sample's participation in organised sport probably was exercise of sufficiently vigorous intensity; however, the boys participated in different sport events, such as basketball, volleyball, soccer, etc., and were too young to specialise in only one sport. Therefore, the extracurricular training consisted more or less of different sport games, elementary sport-specific exercises, technique, etc., compared to official physical education lessons, which generally are moderate-to-vigorous physical activities. This may not have been enough to observe statistically significant relationships between serum leptin and physical activity. High intensity physical activity influences leptin levels, in part, because physical activity *per se* is a metabolic regulator for several hormone (insulin/insulin resistance) sensitivities, which could consequently affect leptin levels (Jimenez-Pavon, Ortega, Artero, Labayen, Vicente-Rodriguez, Huybrechts, *et al.*, 2012). In contrast, moderate intensity physical activity results in reduced abdominal fat for leptin synthesis (Racette, Coppack, Landt, & Klein, 1997). It is possible that, in this study, regular physical activity decreased body fat mass in at least some boys; however, leptin levels remained high. One concern is that cessation of regular exercise by boys with high leptin levels may result in an increase of body mass, further increasing leptin levels and increasing fat deposition.

It is well known that there are large variations in serum leptin levels among individuals with similar BMI through childhood and adolescence (Clayton, Gill, Hall, Tillmann, Whatmore, & Price, 1997). This was also observed in the current sample. In connection with this observation, the sample was divided into three subgroups by leptin level, using one standard deviation above and below the mean as the criterion. It was interesting that the only significant correlation was found in the high leptin group, between leptin levels and moderate physical activity in 30-min. sessions at least five times per week. Interestingly, in this high leptin group were only sport participants who were tall and whose body-fat mass was probably relatively high. They were taller, heavier, and their BMI was higher

than those of other groups (Table 1). During puberty, leptin concentration reaches a peak at Tanner Stage 2 for boys (Roemmich, *et al.*, 1998; Romon, *et al.*, 2004). This is one of the explanations for the concentration being very high, especially in the high leptin group. For some physically active slim boys on the low leptin group, the proximity threshold may have hampered detection of the effects of physical activity on leptin concentration (Romon, *et al.*, 2004).

Limitations and Conclusions

Some limitations of the study merit consideration. The first is the cross-sectional design, which leaves many questions about the causalities involved. Second, there may be a relatively high rate of error from the use of self-reported physical activity. Third, the results are valid only for a very select group of 10- to 12-year-old boys (physically active, normal BMI, and Tanner Stage 2) from one city and the surrounding area. Using self-assessed Tanner stage is a routine and frequently employed sexual maturation parameter, with the possibility of relatively high error. Better parameters such as wrist x-rays or blood testosterone concentration measurements are more accurate.

For the first time, the correlation between physical activity and serum leptin concentrations were studied in non-obese, healthy, peripubertal boys. It appears that if leptin levels are high in boys with normal BMI, then very vigorous physical activity is not necessary to lower leptin levels. The novelty of this study is that significant correlations between physical activity of moderate intensity and leptin levels were observed in boys with high leptin levels. For boys with normal BMI whose leptin levels are elevated, it is enough to exercise regularly at moderate intensity. It is necessary to discover the reasons why leptin levels may be elevated, and whether this is associated with a higher risk of overweight in the future.

Correlations between physical activity and serum leptin levels are weak in this study. Only regular moderate physical activity correlated significantly with leptin levels, and only in the high leptin group. Relatively intensive sport participation outside school and taking part in obligatory physical education lessons were not significant factors in leptin levels.

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