Attenuation of the Effect of the FTO rs9939609 Polymorphism on Total and Central Body Fat by Physical Activity in Adolescents

The HELENA Study

Jonatan R. Ruiz, PhD; Idoia Labayen, PhD; Francisco B. Ortega, PhD; Vanessa Legry, PhD; Luis A. Moreno, MD, PhD; Jean Dallongeville, MD, PhD; David Martínez-Gómez, BSc; Szilvia Bokor, MD, PhD; Yannis Manios, PhD; Donatella Ciarapica, PhD; Frederic Gottrand, MD, PhD; Stefaan De Henauw, MD, PhD; Michael Sjöström, MD, PhD; Aline Meirhaeghe, PhD; for the HELENA Study Group

Objective: To examine whether physical activity attenuates the effect of the FTO rs9939609 polymorphism on body fat estimates in adolescents.

Design: Cross-sectional study.

Setting: Athens, Greece; Dortmund, Germany; Ghent, Belgium; Heraklion, Greece; Lille, France; Pécs, Hungary; Rome, Italy; Stockholm, Sweden; Vienna, Austria; and Zaragoza, Spain, from October 2006 to December 2007.

Participants: Adolescents from the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study (n = 752).

Main Exposure: Physical activity.

Main Outcome Measures: The FTO rs9939609 polymorphism was genotyped. Physical activity was assessed by accelerometry. We measured weight, height, waist circumference, and triceps and subscapular skinfolds; body mass index (BMI [calculated as weight in kilograms divided by height in meters squared]) and body fat percentage were calculated.

Results: The A allele of the FTO polymorphism was significantly associated with higher BMI (+0.42 per risk allele), higher body fat percentage (+1.03% per risk allele), and higher waist circumference (+0.85 cm per risk allele). We detected significant or borderline gene × physical activity interactions for the studied body fat estimates (for interaction, $P = .02, .06, \text{and } .10$ for BMI, body fat percentage, and waist circumference, respectively). Indeed, the effect of the FTO rs9939609 polymorphism on these body fat parameters was much lower in adolescents who met the daily physical activity recommendations (ie, $\geq 60 \text{ min/d}$ of moderate to vigorous physical activity) compared with those who did not: $+0.17 \text{ vs } +0.65$ per risk allele in BMI, respectively; $+0.40\% \text{ vs } +1.70\%$ per risk allele in body fat percentage, respectively; and $+0.60 \text{ vs } +1.15 \text{ cm}$ per risk allele in waist circumference, respectively.

Conclusion: Adolescents meeting the daily physical activity recommendations may overcome the effect of the FTO rs9939609 polymorphism on obesity-related traits.

activity objectively assessed by accelerometry on body mass index (BMI), body fat percentage, and waist circumference and to assess whether meeting the daily physical activity recommendations could abolish the deleterious effect of the FTO rs9939609 polymorphism on body fat estimates in a cohort of European adolescents.

**METHODS**

**PARTICIPANTS**

Adolescents were part of the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study (HELENA-CSS). The HELENA-CSS was designed to obtain reliable and comparable data on nutrition and health-related parameters of a sample of European adolescents.20 A total of 3865 adolescents were recruited between October 2006 and December 2007. Adolescents were randomly selected from schools using a proportional cluster sampling taking into account geographical distribution in each city, private/public school ratio, and number of classes by school. One-third of the classes were randomly selected for blood collection, resulting in a total of 1155 blood samples for the subsequent clinical biochemistry assays and genetic analyses. Among these participants, 752 adolescents (413 girls) with data on FTO rs9939609, BMI, and physical activity were included in this study (namely, the final sample). The 2 samples (the “blood” sample and the “final” sample) were similar in terms of genotype frequencies (TT: 37.9 vs 36.6, respectively; TA: 45.5 vs 47.1, respectively; and AA: 16.7 vs 16.4, respectively; P = .87) and levels of moderate to vigorous physical activity (mean [SD], 45.6 [17.7] vs 40.4 [14.0] min/d, respectively; P = .41), whereas the BMIs were different (mean [SD], 22.7 [5.6] vs 21.7 [6.8], respectively; P < .001). After receiving complete information about the aims and methods of the study, all adolescents and their parents or guardians were fully informed and signed an informed written consent. All participants met the general HELENA-CSS inclusion criteria.18,19 The study was performed following the ethical guidelines of the Declaration of Helsinki 1961 (revision of Edinburgh 2000), Good Clinical Practice, and legislation about clinical research in humans (I). The protocol was approved by the corresponding local human research review committees of the centers involved.20

**ASSESSMENT OF BODY FAT**

Weight and height were measured following standard procedures,21 and BMI was calculated as weight in kilograms divided by height in meters squared. Waist circumference was measured in triplicate at the midpoint between the superior iliac spine and the costal edge in the midaxillary line with an anthropometric inelastic tape (SECA 200; Seca Deutschland, Hamburg, Germany) and was used as a surrogate measure of central body fat. It was recorded to the nearest 0.1 cm. Skinfold thickness was measured to the nearest 0.2 mm in triplicate on the left side at the biceps, triceps, subscapularis, suprailium, thigh, and medial calf with a Holtain Caliper (Holtain Ltd, Crymmych, Wales).21 Body fat percentage was calculated from skinfold thicknesses (triceps and subscapularis) using the equations by Slaughter et al.22

**ASSESSMENT OF PUBERTAL STATUS**

Pubertal stage was recorded by a trained researcher of the same sex as the child, according to Tanner and Whitehouse23 and as described elsewhere.24

**RESULTS**

Characteristics of the study sample are shown in the Table. Genotype frequencies were 275 (0.37%), 354

---

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>339</td>
<td>14.5 (1.4)</td>
</tr>
<tr>
<td>BMI</td>
<td>339</td>
<td>20.6 (3.3)</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>330</td>
<td>19.3 (10.6)</td>
</tr>
<tr>
<td>Waist circum. cm</td>
<td>313</td>
<td>72.7 (7.9)</td>
</tr>
<tr>
<td>Moderate to vigorous PA, min/d</td>
<td>339</td>
<td>68.1 (25.2)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); PA, physical activity.

a At least 60 min/d of moderate to vigorous PA.17,24

---

**ASSESSMENT OF PHYSICAL ACTIVITY**

Physical activity was assessed during 7 consecutive days with a uniaxial accelerometer (GT1M; ActiGraph, Pensacola, Florida) attached to the lower back. Adolescents were instructed to wear the accelerometer during all time awake and to remove it only during water-based activities. At least 3 days of recording with a minimum of 8 hours registered per day was set as an inclusion criterion. The time-sampling interval (epoch) was set at 15 seconds.25 We calculated the time engaged in at least moderate physical activity (≥3 metabolic equivalents) based on a standardized cutoff of 2000 counts/min or more. Moderate to vigorous physical activity was dichotomized into less than 60 min/d and 60 min/d or longer.17,26

**GENOTYPING**

The FTO rs9939609 genotyping was done by an Illumina system (Illumina, Inc, San Diego, California) using the GoldenGate technology (GoldenGate Software, Inc, San Francisco, California). The genotyping success rate was 100%. The genotype distribution respected Hardy-Weinberg equilibrium (P=.56).

**STATISTICAL ANALYSIS**

The genotypes were coded as an ordinal variable (ie, 0=TT, 1=TA, 2=AA). We analyzed the differences in body fat estimates (BMI, body fat percentage, and waist circumference) between the 3 FTO rs9939609 genotypes with an additive model using a mixed-effects linear regression model with random intercept allowing the center effects to be random and with age and sex as potential confounders (fixed effects). To test for the existence of an interaction between the FTO rs9939609 polymorphism and moderate to vigorous physical activity (<60 min/d and ≥60 min/d) on body fat estimates (BMI, body fat percentage, and waist circumference), we used the same model but added the cross-product term FTO × physical activity. Finally, we repeated the analyses stratified by moderate to vigorous physical activity categories (<60 min/d and ≥60 min/d) of moderate to vigorous physical activity.

Analyses were performed using SPSS version 16.0 statistical software for Windows (SPSS Inc, Chicago, Illinois). The level of significance was set to .05 for all but the interaction effect, which was considered to .10.
We observed that the minor A allele of the FTO polymorphism was significantly associated with higher BMI (0.42 per risk allele; 95% confidence interval [CI], 0.10 to 0.75; \( P = .01 \)), higher body fat percentage (1.03% per risk allele; 95% CI, 0.19 to 1.88; \( P = .02 \)), and higher waist circumference (0.85 cm per risk allele; 95% CI, 0.04 to 1.66; \( P = .04 \)) after adjusting for age, sex, and center (Figure 1). Indeed, in those adolescents who spent less than 60 min/d participating in moderate to vigorous physical activity (n=441 [59%]), the A allele of the FTO polymorphism was significantly associated with higher BMI (0.65 per risk allele; 95% CI, 0.21 to 1.10; \( P = .005 \)), higher body fat percentage (1.70% per risk allele; 95% CI, 0.58 to 2.81; \( P = .003 \)), and higher waist circumference (1.15 cm per risk allele; 95% CI, 0.04 to 2.26; \( P = .04 \)) after adjusting for center, sex, and age (Figure 2). In contrast, in those adolescents who

ASSOCIATION BETWEEN THE FTO rs9939609 POLYMORPHISM AND BODY FAT ESTIMATES

We observed that the minor A allele of the FTO polymorphism was significantly associated with higher BMI (0.42 per risk allele; 95% confidence interval [CI], 0.10 to 0.75; \( P = .01 \)), higher body fat percentage (1.03% per risk allele; 95% CI, 0.19 to 1.88; \( P = .02 \)), and higher waist circumference (0.85 cm per risk allele; 95% CI, 0.04 to 1.66; \( P = .04 \)) after adjusting for age, sex, and center (Figure 1).

INTERACTION BETWEEN THE FTO rs9939609 POLYMORPHISM AND PHYSICAL ACTIVITY

We did not observe significant differences among the FTO genotypes in time spent participating in moderate to vigorous physical activity (mean [SD], 61.2 [24.1], 57.1 [23.2], and 60.1 [24.3] min/d for the TT, TA, and AA genotypes, respectively; \( P = .54 \)). We observed significant interactions between the FTO polymorphism and physical activity (60 and \( \geq 60 \) min/d of moderate to vigorous physical activity) when considering BMI (for interaction, \( P = .02 \)), body fat percentage (for interaction, \( P = .06 \)), or waist circumference (for interaction, \( P = .10 \)). Indeed, in those adolescents who spent less than 60 min/d participating in moderate to vigorous physical activity (n=441 [59%]), the A allele of the FTO polymorphism was significantly associated with higher BMI (0.65 per risk allele; 95% CI, 0.21 to 1.10; \( P = .005 \)), higher body fat percentage (1.70% per risk allele; 95% CI, 0.58 to 2.81; \( P = .003 \)), and higher waist circumference (1.15 cm per risk allele; 95% CI, 0.04 to 2.26; \( P = .04 \)) after adjusting for center, sex, and age (Figure 2). In contrast, in those adolescents who

**Figure 1.** Association between the FTO polymorphism rs9939609 and mean body mass index (calculated as weight in kilograms divided by height in meters squared), body fat percentage, and waist circumference. Error bars indicate 95% confidence intervals. Values are adjusted for center, sex, and age.

**Figure 2.** Interaction effect between the FTO polymorphism rs9939609 and levels of moderate to vigorous physical activity (MVPA) (<60 min/d vs \( \geq 60 \) min/d) on mean body mass index (calculated as weight in kilograms divided by height in meters squared), body fat percentage, and waist circumference. Error bars indicate 95% confidence intervals. Values are adjusted for center, sex, and age.
spent at least 60 min/d participating in moderate to vigorous physical activity (n=311), the A allele of the FTO polymorphism was not associated with higher BMI (−0.17 per risk allele; 95% CI, −0.31 to 0.66; P=.56), or waist circumference (−0.40% per risk allele; 95% CI, −0.63 to 1.82; P=.34) after adjusting for center, sex, and age (Figure 2).

The results were similar in boys and girls and were similar when we adjusted for pubertal status instead of age (data not shown). Likewise, the results did not change after further adjusting for height squared in those mod-
els where waist circumference was involved (data not shown).

COMMENT

As expected, the minor A allele of rs9939609 was associated with higher levels of BMI, body fat percentage, and waist circumference in our adolescent population. We observed a gene $\times$ physical activity interaction for all of the study’s body fat estimates, and the stratified analyses ($<60$ and $\geq 60$ min/d of moderate to vigorous physical activity) revealed that the minor A allele was not associated with BMI, body fat percentage, or waist circumference in those adolescents who spent at least 60 min/d participating in moderate to vigorous physical activity. These findings have important public health implications and indicate that meeting the physical activity recommendations may offset the genetic predisposition to obesity associated with the FTO polymorphism in adolescents.

The results of this study are consistent with the findings of previous studies showing an association between FTO polymorphisms and obesity-related traits in different ethnic populations in adults, adolescents, or children. Further, we confirm that the association between the FTO rs9939609 polymorphism and adiposity estimates was attenuated once we took into account the genetic predisposition to obesity associated with the FTO polymorphism in adolescents.

To our knowledge, our study is the first to report an interaction between the FTO rs9939609 polymorphism and physical activity level on adiposity indices using objectively assessed physical activity in adolescents. Indeed, this study replicates previous findings of gene $\times$ physical activity interaction in adults. Vimaleswaran et al reported an interaction between the FTO rs1121980 polymorphism and self-reported physical activity on BMI ($P=0.004$) and waist circumference ($P=0.02$) in 20,374 adults from the European Prospective Investigation Into Cancer and Nutrition–Norfolk Study. They showed a reduced but still significant ($P<0.001$) effect of the FTO rs1121980 polymorphism on both BMI ($+0.25$ per risk allele) and waist circumference ($+0.64$ cm per risk allele) in physically active individuals compared with the inactive group (BMI, $+0.44$ per risk allele; waist circumference, $+1.04$ cm per risk allele). A similar effect size was observed in the Inter99 study composed of 5,554 middle-aged Danish individuals. Andreasen et al also found an interaction between the FTO rs9939609 polymorphism and self-reported physical activity (for interaction, $P=0.007$). Rampersaud et al observed an interaction between the FTO rs1861868 polymorphism and objectively assessed physical activity (for interaction, $P=0.01$) in 704 Old Order Amish individuals. They reported that the increase per risk allele in BMI was attenuated in individuals in the upper half of the physical activity distribution ($+0.30$ per risk allele) compared with individuals within the lower half of the physical activity distribution ($+1.12$ per risk allele). Despite participants’ differences in age and ethnicity, the effect sizes observed in our study are similar to those reported previously.

Our findings do not concur, however, with other studies that failed to observe an interaction between the FTO polymorphism and physical activity. For example, Hakanen et al found no interaction between the FTO rs9939609 polymorphism and leisure-time physical activity in 438 Finnish adolescents aged 15 years. It is worth noting that most of the earlier-mentioned studies assessed physical activity by a self-reported questionnaire, whereas we assessed physical activity by an objective method (i.e., accelerometry). It is known that the assessment of physical activity by questionnaire may have lower accuracy, especially in young people. In epidemiologic research, self-reported questionnaires are common tools to assess physical activity level because they are easy to use and inexpensive. However, the sporadic nature of youths’ physical activity makes these activities difficult to recall, quantify, and categorize. Also, youths have a lesser ability to accurately recall intensity, frequency, and especially duration of the activities.

Findings from our study should be taken with caution owing to its cross-sectional nature. Lifestyle intervention studies in adolescents are needed to determine to what extent the effect of FTO on obesity-related traits can be modified, especially in genetically predisposed individuals. Findings from lifestyle intervention studies in adults are promising. Franks et al reported that the genetic (FTO rs9939609 polymorphism) effect on subcutaneous adipose tissue gain tended to be attenuated ($P=0.05$) after a 1-year program of intensive lifestyle intervention.

In conclusion, our results suggest that physical activity can ameliorate the deleterious effect of the FTO rs9939609 polymorphism on body fat estimates in adolescents. Indeed, adolescents meeting the daily physical activity recommendations may overcome the effect of this gene on obesity-related traits.

Accepted for Publication: November 17, 2009.

Author Affiliations: Unit for Preventive Nutrition, Department of Biosciences and Nutrition at NOVUM, Karolinska Institutet, Huddinge, Sweden (Drs Ruiz, Ortega, and Sjöström); Department of Nutrition and Food Science, University of the Basque Country, Vitoria, Spain (Dr Lagayen); Department of Physiology, University of Granada, Granada, Spain; Institut National de la Santé et la Recherche Médicale Unit 744, Institut Pasteur de Lille, Université Lille Nord de France, and Université Droit et Santé de Lille (Drs Legry, Dallongeville, Bokor, and Meirhaeghe) and Department of Medicine, University of Lille, and Department of Pediatrics, Jeanne de Flandre Children’s University Hospital (Dr Gottrand), Lille, France; Growth, Exercise, Nutrition, and Development Research Group, University School of Health Sciences, University of Zaragoza, Zaragoza, Spain (Dr Moreno); Immunonutrition Research Group, Department of Metabolism and Nutrition, Instituto del Frío, Institute of Food Science, Technology, and Nutrition, Spanish National Research Council, Madrid, Spain (Mr Martinez-Gómez); Department of Nutrition and Dietetics, Harokopio University, Athens, Greece (Dr Manios); National Research Institute for Food and Nutrition, Roma, Italy (Dr Ciarapica); Department of Public Health, Ghent University Hospital, Ghent, Belgium (Dr De Henauw); and Department of Pediatrics, University of Pécs, Pécs, Hungary (Dr Molnár).

Correspondence: Jonatan R. Ruiz, PhD, Unit for Preventive Nutrition, Department of Biosciences and Nu-
tribution at NOVUM, Karolinska Institutet, Halsvågen 7-9, SE-141 57 Huddinge, Sweden (ruiz@ugr.es).

Author Contributions: Dr Ruiz had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Ruiz, Dallongeville, Gottrand, De Henauw, and Sjöström. Acquisition of data: Ruiz, Ciarapica, Gottrand, Molnár, and Sjöström. Analysis and interpretation of data: Ruiz, Labayen, Ortega, Legry, Moreno, Dallongeville, Martínez-Gómez, Bokor, Manios, Sjöström, and Meirhaeghe. Drafting of the manuscript: Ruiz, Ciarapica, Sjöström, and Meirhaeghe. Critical revision of the manuscript for important intellectual content: Ruiz, Labayen, Ortega, Legry, Moreno, Dallongeville, Martínez-Gómez, Bokor, Manios, Gottrand, De Henauw, Molnár, and Sjöström. Statistical analysis: Ruiz, Legry, Dallongeville, and Meirhaeghe. Obtained funding: Ruiz, Moreno, Dallongeville, De Henauw, and Sjöström. Administrative, technical, and material support: Labayen, Ortega, Moreno, Gottrand, De Henauw, and Sjöström. Study supervision: Ruiz, Dallongeville, Molnár, Sjöström, and Meirhaeghe.

Financial Disclosure: None reported.

Funding/Support: The HELENA Study is supported by contract FOOD-CT-2005-007034 from the European Community Sixth RTD Framework Programme. This study is also supported by grants EX-2007-1124, EX-2008-0641, and AP2006-02464 from the Spanish Ministry of Education, grant RD08/0072 from the Maternal, Child Health, and Development Network of the Spanish Ministry of Health, the Swedish Council for Working Life and Social Research, and the ALPHA study (a European Union–funded study in the framework of the Public Health Programme [reference number 20061201]).

Disclaimer: The content of this article reflects only the authors’ views. The additional HELENA Study Group members are not responsible for the content, and the European Community is not liable for any use that may be made of the information contained herein.

REFERENCES


