Are Muscular and Cardiovascular Fitness Partially Programmed at Birth? Role of Body Composition

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Objective To determine whether birth weight is associated with handgrip strength and cardiovascular fitness in adolescence and, if so, how these associations are influenced by current body composition.

Study design A total of 1801 adolescents (983 females), age 13 to 18.5 years, from the AVENA (Alimentación y Valoración del Estado Nutricional de los Adolescentes Españoles [Food and Assessment of the Nutritional Status of Spanish Adolescents]) study were evaluated. Handgrip strength and cardiovascular fitness were assessed using the handgrip test and the 20-m shuttle run test, respectively.

Results Birth weight was positively associated with handgrip strength in females after controlling for current age, gestational age, breast-feeding, and adolescent body mass index ($P = .002$), body fat percentage ($P < .001$), or waist circumference ($P = .005$), but not after controlling for fat-free mass. The associations were similar yet weaker in males. Females with high birth weight (>90th percentile) had greater handgrip strength than those with normal (10th to 90th percentile) or low (<10th percentile) birth weight, after adjusting for body fat percentage ($P = .004$). All of the differences became nonsignificant after adjusting for adolescent fat-free mass. Birth weight was not associated with cardiovascular fitness.

Conclusions High birth weight is associated with greater handgrip strength in adolescents, especially in females, yet these associations seem to be highly explained by fat-free mass. *(J Pediatr 2009;154:61-6)*

The nutritional and hormonal milieu of the fetus is an indirect consequence of the maternal lifestyle, particularly in relation to nutrition and physical exercise.[1,2] It has been hypothesized that intrauterine undernutrition or overnutrition can alter the gene expression of the fetus, causing developmental adaptations that may lead to permanent changes in physiology and metabolism that may have consequences later in life.[3,4] Birth weight is an established index of the intrauterine condition and has a known programming effect on later body size and body composition.[4,5] Less is known about the associations between birth weight and physical fitness later in life, however.

Muscular strength and cardiovascular fitness are main components of physical fitness. Both are considered emerging risk factors for cardiovascular disease and powerful health markers already at childhood and adolescence.[6] Thus, it is of interest to examine the associations of birth weight with handgrip strength and cardiovascular fitness, and to investigate how these associations are modified by body size and body composition. A lower physical fitness level, including strength and cardiovascular fitness, has been reported in extremely low birth weight preterm children and adolescents compared with their term-born peers,[7,8] but less is known about the programming effect of birth weight on these physical fitness components in adolescents who were born at term.

AVENA	Alimentación y Valoración del Estado Nutricional de los Adolescentes (Feeding and Assessment of Nutritional Status of Spanish Adolescents)	BF%	Body fat percentage
		BMI	Body mass index
		FFM	Fat-free mass
		VO_{2max}	Maximal oxygen consumption
ANCOVA	Analysis of covariance	WC	Waist circumference

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The present study evaluated the relationship of birth weight with both handgrip strength and cardiovascular fitness in a large sample of healthy Spanish adolescents and examined how these associations are influenced by body size and body composition.

METHODS

The data were gathered as a part of the AVENA (Alimentación y Valoración del Estado Nutricional de los Adolescentes Españoles [Food and Assessment of the Nutritional Status of Spanish Adolescents]) study. The complete methodology has been published elsewhere.[9] In brief, the AVENA participants were adolescents age 13 to 18.5 years. Individuals from public and private secondary schools and technical colleges were included. Sampling was multistaged, performed at random, and stratified by town of origin (5 Spanish cities), socioeconomic status, sex, and age. Subjects with metabolic diseases, who were pregnant, or who abused alcohol or drugs were excluded. Alcohol or drug abuse was defined as the usual consumption of drugs (alcohol, amphetamines, barbiturates, benzodiazepines, cocaine, methaqualone, and opium alkaloids) for a nontheraupetic or nonmedical purpose. It was determined by confidential interview.

Body mass index (BMI), the variable that demonstrated the greatest variance in a previous study also conducted in an adolescent population,[10] was used to determine the sample size. A total of 2100 subjects was deemed necessary for the full study to be representative of the population. The subjects were distributed by cities and proportionally by sex and age (13, 14, 15, 16, and 17 to 18.5 years). After excluding those adolescents in whom data on birth weight, gestational age, or handgrip strength were not available, as well as those born at <35 weeks' gestation, a total of 1801 adolescents (818 males and 983 females) were included in this study.

Written consent to participate was obtained from both the adolescents and their parents. The study protocol was developed in accordance with the ethical standards of the revised Declaration of Helsinki and was approved by the Review Committee for Research Involving Human Subjects of the Hospital Universitario Marqués de Valdecilla, Santander, Spain.

Birth weight (kg) and gestational age at birth were obtained from health records.[5,11] Most of the subjects (85.8% of the males and 85.6% of the females) were born between 35 and 40 weeks' gestation. Reference values for handgrip strength and cardiovascular fitness, as well as detailed information about the protocol, have been reported by Ortega et al.[12] In brief, handgrip strength was assessed using a hand dynamometer with adjustable grip (TKK 5101 Grip D; Takey, Tokio, Japan). Two attempts per hand were performed, and the best score was used. The average of the best scores achieved by each hand was used in the analysis. Cardiovascular fitness was assessed by means of the 20-m shuttle run test, as described in detail by Léger et al.[13] In brief, the subjects were required to run between 2 lines 20 m apart while keeping pace with audio signals emitted from a prerecorded CD. The initial speed was 8.5 km/h, and the speed was increased by 0.5 km/h per minute. The test was completed when the subject failed to reach the end lines concurrent with the audio signals on 2 consecutive occasions, or when the subject stopped because of fatigue. The equations of Léger et al,[13] previously validated in children and adolescents,[13,14] were used to estimate the maximum oxygen consumption (VO_{2max}) from the test scores.

Reference values of anthropometric and body composition indices, as well as the description of the procedures used in the AVENA study, have been published previously.[15] In brief, weight and height were measured, and BMI was calculated as weight (in kilograms)/height (in meters) squared. Waist circumference (WC) was measured, using an inelastic tape, horizontally midway between the lowest rib margin and the iliac crest at the end of gentle expiration. Body fat percentage (BF%) was calculated from skinfold thicknesses using Slaughter's equations.[16] Fat-free mass (FFM), in kilograms, was derived by subtracting fat mass from total body weight. Pubertal status was self-reported and classified according to the method of Tanner and Whitehouse.[17]

Some factors potentially related to birth weight, physical fitness, and body composition also were investigated. Parents were asked to answer the following question concerning breast-feeding: "How long was your child breast-fed?" The possible answers were only by baby bottle, baby bottle + breast, <1 month, ≥1 and <2 months, ≥2 and <3 months, ≥3 and <4 months, ≥4 and <5 months, and ≥5 months.

Leisure-time sporting activity was determined from the adolescent's answers to a question designed specifically for the AVENA study:[9] "Do you undertake any physical sporting activity after school?" The answer was classified as either no physical sporting activity or 1 or more physical sporting activities. The time spent in television viewing also was self-reported by the adolescents and classified as either ≤2 hours/day or >2 hours/day.

Physical characteristics of the study sample by sex are presented as means and standard deviations, unless stated otherwise. Variables with a skewed distribution were log-transformed to obtain a more symmetrical distribution. Given that in previous work conducted in this same sample we found interaction factors for sex × birth weight with adolescent body composition,[18] all analyses were performed separately for males and females.

After bivariate correlation analysis (Pearson correlation) among the main study variables, the relationships between birth weight, handgrip strength, and cardiovascular fitness (VO_{2max}) were analyzed by linear regression in an extended-model approach. Model I included only the predictor (birth weight) and the dependent variable (either handgrip strength or cardiovascular fitness). For model II, a set of confounders (ie, current age, gestational age, and breast-feeding) was entered into the model. For model III, height also was entered into the model (confounders + height). For model IV, BMI was entered into the model instead of height (confounders + BMI). For model V, FFM was entered into the model instead of BMI (confounders + FFM). For model VI, BF% was