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Short Report

High Fitness is Associated with a Healthier Programming of Body Composition at Adolescence

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ABSTRACT The programming effect of birth weight on later body composition has become of increasing interest in recent years. This programming effect is affected by factors such as gender. Physical fitness could be another factor of influence. This study aimed to examine whether handgrip strength (HG) or cardiovascular fitness (CVF) modify the associations between birth weight and body composition in adolescents. A sample of 1,740 (942 females) adolescents aged 13 to 18.5 years, born at more than 35 weeks of gestation, from the AVENA study was studied. Waist circumference was measured, percentage body fat was calculated from skinfold thicknesses and fat free mass was derived by subtracting fat mass from total body weight. HG and CVF were assessed using the HG test and the 20 m shuttle run test, respectively. Birth weight was positively associated with fat free mass in females with high (above the median) CVF ($P < 0.001$), but not in those with low (below the median) CVF. In contrast, birth weight was positively associated with total and central adiposity in males with low HG (both $P = 0.002$), but not in those with high HG. These results suggest that the programming effect of birth weight on later body composition is dependent on gender and fitness level. A high birth weight may have a healthy programming effect on body composition in those adolescents with a high fitness level, being associated with increased fat free mass levels in females and not showing the increased adiposity levels observed in unfit males. Am. J. Hum. Biol. 20:732–734, 2008. © 2008 Wiley-Liss, Inc.

The programming effect of birth weight, a surrogate of the intrauterine conditions, on body composition at childhood and adolescence has become of increasing interest in pediatrics and epidemiology in recent years (Labayen et al., 2006; Wells et al., 2007; Yliharsila et al., 2007). It is hypothesized that intrauterine under- or over-nutrition 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 (Fernandez-Twinn and Ozanne, 2006). We have previously shown that this programming effect is affected by gender (Labayen et al., 2008). Body weight at birth is associated with fat free mass in female adolescents, whereas in male adolescents is associated with total and central adiposity. Physical fitness level could be another factor of influence.

Muscular strength and cardiovascular fitness (CVF) are emerging risk factors and powerful health markers for cardiovascular disease already at childhood and adolescence (Ortega et al., 2008). There is evidence indicating that they interact with fatness in relation to several health outcomes (Ortega et al., 2008). Whether the association between birth weight and adolescent body composition is influenced by physical fitness remains to be elucidated.

This study aimed to examine whether handgrip strength (HG) or CVF modify the associations between birth weight and body composition in healthy female and male adolescents.

METHODS

Study design

A sample of 1,740 Spanish adolescents (942 females and 798 males aged 13–18.5 years) from the AVENA study (Gonzalez-Gross et al., 2003; Moreno et al., 2003), with complete and valid data for birth weight and body composition variables, were included in this study. The fact to be born at 35 weeks of gestation or more was an additional inclusion criterion. Written consent to participate was obtained from both parents and adolescents. The study protocol was performed in accordance with the ethical standards laid down in the 1975 Declaration of Helsinki (as revised in Hong-Kong in 1989 and in Edinburgh in 2000), and approved by the Review Committee for

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TABLE 1. Linear regression statistics showing estimated change in mean fat free mass, percentage body fat and waist circumference per kilogram increase in birth weight for female and male adolescents

		Birth weight (kg)									
		Females					Males				
		N	β	95% CI		*P*	*N*	β	95% CI		*P*
Fat free mass (kg)	No confounder	942	2.152	1.576	2.727	<0.001	798	2.006	1.018	2.995	<0.001
	Confounders	932	0.948	0.462	1.433	<0.001	791	0.349	−0.252	0.950	0.255
	Confounders + HG	932	0.805	0.358	1.252	<0.001	791	0.403	−0.123	0.929	0.133
	Confounders + CVF[a]	788	0.895	0.386	1.404	0.001	710	0.369	−0.263	1.002	0.252
Percentage body fat[b]	No confounder	942	1.47%	−1.52%	4.45%	0.335	798	7.48%	1.74%	13.22%	0.011
	Confounders	932	1.67%	−1.45%	4.79%	0.293	791	7.34%	1.41%	13.27%	0.015
	Confounders + HG[c]	932	1.33%	−1.76%	4.42%	0.399	791	7.42%	1.50%	13.35%	0.014
	Confounders + CVF	788	1.42%	−1.75%	4.60%	0.380	710	9.45%	3.90%	14.99%	0.001
Waist circumference (cm)[b]	No confounder	942	1.95%	0.59%	3.31%	0.005	798	3.37%	1.89%	4.86%	<0.001
	Confounders	933	1.21%	−0.17%	2.59%	0.086	792	2.38%	0.92%	3.85%	0.001
	Confounders + HG[c]	933	0.95%	−0.39%	2.29%	0.165	792	2.44%	1.00%	3.87%	0.001
	Confounders + CVF	789	1.06%	−0.38%	2.49%	0.148	712	2.74%	1.29%	4.18%	<0.001

The confounders entered into the model were: gestational age, breast feeding, and current age and height. CI, confidence intervals; HG, handgrip strength; CVF, cardiovascular fitness.
[a]An interaction was found in females (i.e. birth weight × cardiovascular fitness, $P = 0.003$).
[b]Log transformed variables were used in the analysis and the regression coefficients are shown as the relative change (%) per kg increase in birth weight (i.e. $100 \times \beta_{Ln}$).
[c]Interactions were found in males (i.e. birth weight × handgrip strength; $P = 0.025$ and $P = 0.042$ for percentage body fat and waist circumference, respectively).

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Measurements

Birth weight and gestational age at birth were obtained from health records. The parents were asked to answer the question of how many months the child was breastfed. The harmonization and standardization of anthropometric measurements used in the AVENA study was strictly controlled and has been published elsewhere (Moreno et al., 2003). Weight and height were measured. Body mass index was calculated as weight divided by height squared (kg/m^2), and used to classify the adolescents as overweight (including obesity) and nonoverweight (Cole et al., 2000). Percentage body fat was calculated from skinfold thickness using Slaughter's equations (Slaughter et al., 1988), and fat free mass (kg) was derived by subtracting fat mass from total body weight. Waist circumference was measured as a surrogate of central adiposity. Sexual maturation status was assessed according to Tanner and Whitehouse (Tanner and Whitehouse, 1976). HG and CVF were measured using the HG test and the 20 m shuttle run test, respectively, as previously described (Ortega et al., 2005).

Statistical analysis

To examine the associations between birth weight and body composition in adolescents, and the role of HG and CVF in these associations, the following linear regression models were performed:

Model I examines the association between birth weight and one of the body composition variables, i.e. fat free mass, percentage body fat, and waist circumference. Model II examines the association between birth weight and one of the above mentioned body composition variables after controlling for a set of confounders, i.e. gestational age, breast feeding, and current age and height. In model III, model II additionally controlled for HG (confounders + HG). In model IV, model II additionally controlled for CVF (confounders + CVF). Variables with skewed distribution were log transformed to obtain a more symmetrical distribution.

Interaction factors between the main exposures (i.e. birth weight × HG and birth weight × cardiovascular fitness) with body composition variables were analyzed. Finally, the associations between birth weight and body composition variables were separately analyzed according to HG (low/high HG) or CVF (low/high CVF), in those cases in which interactions were found. HG and CVF levels were dichotomized (low/high) when being below/above the sex-specific median.

All calculations were performed using SPSS v.15.0 software for Windows. For all analyses, the significance level was 5%.

RESULTS AND DISCUSSION

A positive association was observed between birth weight and fat free mass ($P \leq 0.001$) in female adolescents and birth weight and adiposity (percentage body fat and waist circumference, both $P \leq 0.001$) in male adolescents after controlling for gestational age, breast feeding, and current age and height (Table 1). These associations remained unchanged after additional controlling for HG or CVF (Table 1). The results were not substantially altered when sexual maturation status was entered into the models instead of age.

Interestingly, significant interactions were found for birth weight × CVF in relation to fat free mass in females ($P = 0.003$), and for birth weight × HG in relation to percentage body fat and waist circumference in males ($P = 0.025$, and $P = 0.042$, respectively). The different behaviour of the regression slopes in females with low or high CVF and in males with low or high HG levels are shown in Figure 1. Birth weight was positively associated with fat free mass in females with high CVF ($P < 0.001$), whereas no association was observed in females with low cardiovascular fitness. On the other hand, birth weight was positively associated with percentage body fat and waist circumference in males with low HG (both $P = 0.002$), whereas no association was observed in males with high handgrip strength.

It can be identified a common link explaining how physical fitness modifies the associations between birth weight

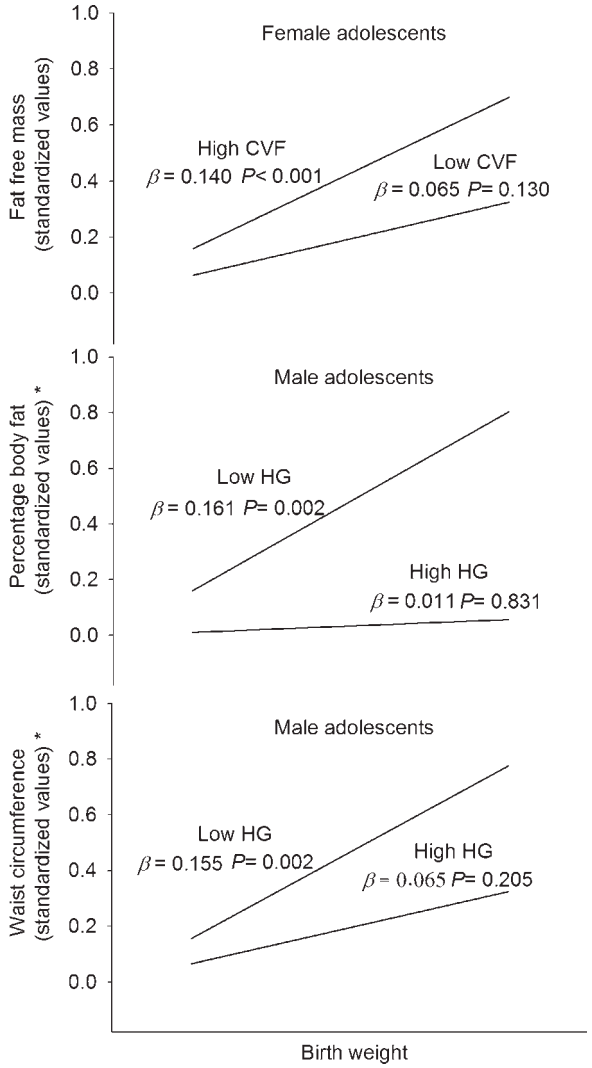

Fig. 1. Graphical representation of the interactions found in females between birth weight and cardiovascular fitness (CVF) in their association with fat free mass, and in males between birth weight and handgrip strength (HG) in their association with total and central adiposity (percentage body fat and waist circumference, respectively). The lines show the standardized regression coefficients (regression slopes) after controlling for gestational age, breast feeding, and current age and height. * Log transformed data were used in the analysis.

and body composition. In the case of females, the individuals with a high fitness level, i.e. high cardiovascular fitness, showed a healthier programming of the body composition, because the higher the birth weight the higher the fat free mass, which has shown many healthy metabolic consequences (Ruiz et al., 2008). In males, the individuals with a high fitness level, i.e. high handgrip strength, did not show any association between birth weight and body composition, whereas an increased adiposity status was shown in their low fit peers with a high birth weight.

It is worthy to hypothesize about the reasons by which a high fitness level is associated with a healthier programming of body composition at adolescence. The available information from large scale epidemiological studies using objective methods for assessing physical activity and findings from randomized controlled trials support that high-intensity physical activity is associated with physical fitness, e.g., CVF and muscular fitness, and that physical exercise programs properly designed and controlled, improve physical fitness in children and adolescents, independent of chronological age, maturation development, and sex (Ortega et al., 2008). Because high intensity physical activity seems to be the key element for physical fitness enhancement and is also associated with a higher fat free mass and lower adiposity, it is reasonable to speculate that a substantial number of people from the high fit groups may also be high vigorously active people and have a healthier body composition at adolescence.

CONCLUSION

Birth weight is positively associated with later fat free mass in those female adolescents with high cardiovascular fitness, and with total and central adiposity in those male adolescents with low handgrip strength. The programming effect of birth weight on fat free mass in females, and on total and central adiposity in males, is dependent on gender and physical fitness level. A high birth weight may have a healthy programming effect on body composition in those adolescents with a high fitness level, being associated with increased fat free mass levels in females and not showing the increased adiposity levels observed in unfit males.

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