Longer Breastfeeding Is Associated with Increased Lower Body Explosive Strength during Adolescence[1,2]

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Abstract

Our aim in this study was to examine the association between breastfeeding duration and cardiorespiratory fitness, isometric strength, and explosive strength during adolescence. A total of 2567 adolescents (1426 girls) from the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) cross-sectional study aged 12.5–17.5 y were included. Information about duration of any and exclusive breastfeeding was obtained retrospectively by means of a parental questionnaire. The 20-m shuttle run, handgrip strength, and standing long jump tests were used to assess physical fitness. Significant differences among the categories of breastfeeding duration were tested using ANCOVA after adjusting for a set of potential confounders: gestational and current age, birth weight, sexual maturation, fat mass, fat-free mass, maternal education, parental weight status, country, smoking behavior, and days of vigorous physical activity. Longer breastfeeding (either any or exclusive) was associated with a higher performance in the standing long jump test in both boys and girls ($P < 0.001$), regardless of fat mass, fat-free mass, and the rest of potential confounders. In adolescents who were breastfed for 3–5 mo or ≥6 mo, the risk of having a standing long jump performance below the 5th percentile was reduced by half compared with those who were never breastfed [odds ratio (OR) = 0.54, 95% CI = 0.30–0.96, $P < 0.05$; and OR = 0.40, 95% CI = 0.22–0.74, $P < 0.01$, respectively). These findings suggest a role of breastfeeding in determining lower body explosive strength during adolescence. J. Nutr. 140: 1989–1995, 2010.

Introduction

Human milk is species specific and all substitute feeding preparations differ markedly from it, making human milk uniquely superior for infant feeding (1). Extensive research documents diverse and compelling advantages from breastfeeding and use of human milk for infants, mothers, families, and society (2). These advantages include health, nutritional, immunologic, developmental, psychological, social, economic, and environmental benefits (3,4).

Physical fitness and body composition, 2 important markers of health throughout life, have been suggested to be influenced by perinatal factors such as breastfeeding (5,6). The association of breastfeeding with body composition has been widely studied (7), yet the relationship is not fully understood (8,9). However,

[1] Supported by the European Community Sixth RTD Framework Programme (contract FOOD-CT-2005-007034 for the HELENA Study) and grants from the Spanish Ministry of Education and Science (AP2005-4358; EX-2008-0641; EX-2009-0899), Spanish Ministry of Education and Science-FEDER funds (Acciones Complementarias DEP2007-29933-E), the Spanish Ministry of Health: Maternal, Child Health and Development Network, no. RD08/0072 (L.M.A.), the ALPHA project, a European Union-funded study in the framework of the Public Health Programme (Ref: 2006120) and the Swedish Heart-Lung Foundation (20090635). The writing group takes sole responsibility for the content of this article. The content of this paper reflects only the authors' views, and the European Community is not liable for any use that may be made of the information contained therein.
[2] Author disclosures: E. G. Artero, F. B. Ortega, V. España-Romero, I. Labayen, I. Huybrechts, A. Papdaki, G. Rodriguez, B. Mauro, K. Widhalm, M. Kersting, Y. Manios, D. Molnar, L. A. Moreno, M. Sjöström, F. Gottrand, M. J. Castillo, and S. De Henauw, no conflicts of interest.
[16] Members of the HELENA Study Group are listed in the Acknowledgments.
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Manuscript received March 04, 2010. Initial review completed May 18, 2010. Revision accepted August 19, 2010.
First published online September 22, 2010; doi:10.3945/jn.110.123596.

there is little research examining the role of breastfeeding in later physical fitness (5). The only study found in the literature reported a lack of association between breastfeeding duration and cardiorespiratory fitness during childhood (5), but there is no evidence regarding other fitness components.

Higher cardiorespiratory and muscular fitness have been associated with a lower cardiovascular and all-cause mortality (10,11). During childhood and adolescence, fitness level is associated with several health indicators, such as total and central adiposity, established and emerging cardiovascular disease risk factors, and skeletal health, among others (12). Because early infant feeding patterns are potentially modifiable, a better understanding of the possible programming effect of breastfeeding on physical fitness is of public health interest.

Our aim in this study was to examine the association between breastfeeding duration and cardiorespiratory fitness, isometric strength, and explosive strength during adolescence.

Materials and Methods

Study design

The current report is based on data derived from the Healthy Lifestyle in Europe by Nutrition in Adolescence cross-sectional study (HELENA-CSS), which aims to obtain standardized, reliable, and comparable data from a random sample of European adolescents on a broad battery of relevant nutrition and health-related markers (13). Data collection took place during 2006 and 2007 in 10 European cities: Athens (inland city) and Heraklion (Mediterranean island city), Greece; Dortmund, Germany; Ghent, Belgium; Lille, France; Pecs, Hungary; Rome, Italy; Stockholm, Sweden; Vienna, Austria; and Zaragoza, Spain. A detailed description of the HELENA-CSS sampling and recruitment approaches, standardization and harmonization processes, data collection, analysis strategies, and quality control activities has been published elsewhere (13).

Study sample

The final HELENA-CSS sample comprised 3528 boys and girls aged 12.5–17.5 y with valid data for gender and BMI. After excluding those adolescents whose data on breastfeeding was not available (n = 782) as well as those born with a gestational age < 35 wk (n = 179), a total of 2567 adolescents (1141 boys and 1426 girls) was finally included in this report. Those adolescents excluded for the analysis were uniformly distributed through the different cities and showed no significant differences in age and BMI compared with those finally included.

All the analyses conducted on the HELENA-CSS data are adjusted by a weighing factor to balance the sample according to sex and age frequencies theoretically calculated at the beginning of the study (same number of boys and girls in all age groups) (14). The study was approved by the Research Ethics Committees of each city involved and was performed following the ethical guidelines of the Declaration of Helsinki 1961 (revision of Edinburgh 2000). Written informed consent was obtained from the parents of the adolescents and the adolescents themselves (15).

Data on breastfeeding history

A parental questionnaire was developed to collect information on the adolescents' birth weight and height, gestational age, and duration of breastfeeding. This questionnaire was sent to the parents together with the study information letter and consent form and collected at school on the first day of the examinations. If information from the parental questionnaire was lacking, the local investigators were advised to send the questionnaire to the parents again to obtain the required information.

Parents were asked about the duration of any and exclusive breastfeeding, the latter being defined as a feeding pattern exclusively based on breast milk with no complementary foods (neither fluid nor solid). Any and exclusive breastfeeding duration were both coded as never, <3 mo, 3–5 mo, and ≥6 mo, consistent with previous research (16).

Physical fitness assessment

Physical fitness was assessed in the HELENA Study by means of the 20-m shuttle run, handgrip strength, and standing long jump tests. The scientific rationale to select these tests, as well as their validity and reliability in young people, has been previously published (17–19).

The field workers were strongly advised to always perform the same fitness test to minimize the potential inter-rater variability within each center. The instructions given to the participants in every test were standardized for all the cities and were translated into the local language to ensure that the same verbal information was given to all participants in the HELENA study. A 5-min standardized warm-up composed of jogging and stretching exercises was performed by the adolescents prior to the fitness testing.

20-m shuttle run test (cardiorespiratory fitness). Participants 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 was increased by 0.5 km/h per minute (1 min equals 1 stage). Participants were instructed to run in a straight line, to pivot on completing a shuttle, and to pace themselves in accordance with the audio signals (20). The test was finished when the participant stopped because of fatigue or failed to reach the end lines concurrent with the audio signals on 2 consecutive occasions. The test was performed once and the last completed stage or half-stage at which the subject dropped out was scored.

Handgrip test (upper body isometric strength). A hand dynamometer with adjustable grip was used (TKK 5101 Grip D; Takey). In standing position, the adolescent squeezed gradually and continuously for at least 2 s, performing the test with the right and left hands in turn, with the elbow in full extension (21). The grip span of the dynamometer was adjusted according to the hand size of the adolescent using an equation specifically developed for adolescents (22). The test was performed twice and the maximum score for each hand was recorded in kilograms. The average of the scores achieved by the left and right hands was used in the analysis.

Standing long jump test (lower body explosive strength). From a starting position immediately behind a line standing with feet approximately shoulder's width apart, the adolescent jumped as far as possible with feet together on a nonslip hard surface. Swinging of the arms and bending of the knees were allowed. The test was performed twice and the best score was recorded in centimeters.

Anthropometric assessment

Harmonization and standardization of anthropometric measurements used to assess body composition in the HELENA Study were strictly controlled and have been previously described (23). Participants were barefoot and wearing underwear. Weight was measured with an electronic scale (Type SECA 861; range, 0.05–130 kg; precision, 0.05 kg) and height was measured in the Frankfurt plane with a telescopic height measuring instrument (Type SECA 225; range, 60–200 cm; precision, 1 mm). BMI was calculated as body weight in kilograms divided by the square of height in meters.

A set of skinfold thicknesses (biceps, triceps, subscapular, suprailiac, thigh, and calf) was measured in triplicate on the left side of the body with a Holtain caliper (range, 0–40 mm; precision, 0.2 mm) (23). Body fat percentage was calculated using Slaughter's equations (24) and fat-free mass was derived by subtracting fat mass from total body weight. For additional analyses, the adolescents were classified as above or below the gender- and age-specific median of fat mass, fat-free mass, and height.

Sexual maturation

Identification of sexual maturation (stages I–V) was assessed by a medical doctor according to Tanner and Whitehouse (25). This standard staging describes breast and pubic hair development in girls and genital and pubic hair development in boys. The first stage corresponds to a prepubertal status and stage V indicates a complete maturation.

Potential confounding factors

Several variables were considered as potential confounders based on previous research (6). Parentally recorded gestational age and birth weight were selected as perinatal confounding factors. Maternal education was reported by the adolescents and classified as elementary, lower secondary, higher secondary, or tertiary education. This variable has been proposed as an appropriate indicator of socioeconomic status (26), which is in turn potentially associated with breastfeeding (6). Parental current weight status was reported by the adolescents as thin/very thin, normal weight, overweight/obese, or unknown. Both paternal and maternal body size have been considered important confounders in the association between breastfeeding and body composition later in life (7). Adolescents' fat mass and fat-free mass were used to adjust for differences in body composition. Physical fitness and body composition are strongly linked to each other (27) and whenever possible they should be analyzed together in relation to health status (28). Adolescents' self-reported smoking behavior (number of cigarettes per week: none, <5, 5–10, 11–20, or >20) and vigorous physical activity during recreation, sport, or leisure time (days per week: between 0 and 7) (29) were used as current lifestyle factors. We included this particular question in our model, because vigorous physical activity, rather than light or moderate, is considered to have a greater effect on an individual's fitness level (30,31).

Statistical analysis

Study sample characteristics are presented as means and SD unless otherwise stated. Gender differences in perinatal and adolescent characteristics were analyzed by 1-way ANOVA for continuous variables and chi-square test for categorical variables. One-way ANOVA was also used to study differences in physical fitness among the different breastfeeding categories. One-way ANCOVA was used to adjust for the different confounders previously mentioned. The residuals of all fitness variables, obtained from ANOVA with sex and categorical age as fixed factors, were graphically checked for normality. The duration of breastfeeding substantially differed among the 10 cities involved in the study (**Table 1**); the analyses were therefore adjusted for geographical distribution (country) in addition to the previous confounders. Because the age of the adolescents at the moment of the study ranged from 12.5 to 17.5 y, age was also considered as a confounder.

All the analyses were done in 2 scenarios, taking the duration of any kind of breastfeeding and the duration of exclusive breastfeeding as the predictor variable of interest, respectively. Similarly, the analyses were redone using sexual maturation as confounder instead of age. Because some significant interaction effects were found for breastfeeding × gender in relation to the studied variables, the results are shown separately for boys and girls.

The association between duration of breastfeeding and standing long jump performance was reanalyzed separately for adolescents with high or low fat mass, fat-free mass, and height. Possible interaction effects for breastfeeding × fat mass, fat-free mass, or height were also analyzed. Finally, we used logistic regression to calculate the odds ratios (OR) and 95% CI of having a standing long jump performance below the 5th percentile (14) in the different breastfeeding categories, adjusting by gender, age, and country. SPSS v. 16.0 for WINDOWS was used and $P <$ 0.05 was considered significant.

TABLE 1 Prevalence of any breastfeeding in the different European cities

		Duration of any breastfeeding			
	n	Never	<3 mo	3 – 5 mo	≥6 mo
			%		
Athens, Greece	205	12.2	27.0	30.0	30.8
Dortmund, Germany	311	26.3	26.0	19.2	28.5
Ghent, Belgium	273	27.2	31.2	24.9	16.0
Heraklion, Crete	165	28.4	44.0	22.7	5.0
Lille, France	217	42.8	33.7	13.9	9.6
Pecs, Hungary	302	6.2	29.4	31.2	33.2
Roma, Italy	280	16.0	27.2	24.3	32.5
Stockholm, Sweden	260	4.6	21.7	23.0	50.7
Vienna, Austria	258	8.4	32.5	23.3	35.8
Zaragoza, Spain	296	14.5	25.8	32.5	27.2
Total	2567	17.9	29.2	24.7	28.1

Results

Perinatal and adolescent characteristics of the study sample were calculated by gender and breastfeeding categories (**Table 2**). On average, 28.1% of European adolescents were breastfed for at least 6 mo, with no significant differences between genders (27.7% in boys and 28.5% in girls). There were no significant differences between boys and girls in mean age and BMI; however, most other characteristics differed between genders ($P < 0.05$).

In the crude analyses (data not shown), as well as in the adjusted models (**Table 3**), the duration of any breastfeeding was positively associated with the performance in the standing long jump test in both boys and girls ($P < 0.001$). The duration of any breastfeeding was also associated with the 20-m shuttle run test in girls ($P < 0.01$), yet this association did not show a clear direction (Table 3).

The association between duration of any breastfeeding and standing long jump performance was further analyzed according to the level of fat mass, fat-free mass, and height (**Fig. 1**). It can be observed that a longer duration of any breastfeeding was associated with a higher performance in the standing long jump test in adolescents with either high or low fat mass, fat-free mass, and height ($P < 0.01$ in all cases).

When exclusive breastfeeding was used as the predictor variable instead of any breastfeeding, the results were virtually the same except for the association between breastfeeding and the 20-m shuttle run test in girls, which became nonsignificant (data not shown). In addition, the results were not altered when sexual maturation status was entered into the model instead of age (data not shown).

Finally, the logistic regression analysis indicated that those adolescents who were breastfed for 3–5 mo or ≥6 mo presented a lower risk of having a standing long jump performance below the 5th percentile compared with those who were never breastfed (OR = 0.54, 95% CI = 0.30–0.96, $P < 0.05$; and OR = 0.40, 95% CI = 0.22–0.74, $P < 0.01$, respectively) after adjusting for gender, age, and country (**Fig. 2**). The results did not change when fat mass, fat-free mass, and height were included in the model. The percentage of adolescents below the 5th percentile was 6.3, 6.7, 3.7, and 2.4% for those adolescents who were never breastfed or breastfed for <3 mo, 3–5 mo, and ≥6 mo, respectively.

Discussion

The main finding of this study was that the duration of either any or exclusive breastfeeding was positively associated with lower body explosive strength regardless of fat mass or fat-free mass and a complete set of potential confounders. In addition, a longer duration of any breastfeeding reduced by one-half the risk of having a standing long jump performance below the 5th percentile, which can be considered an indicator of a possible pathological fitness level (14).

To the best of our knowledge, there are no previous studies examining the association between breastfeeding and muscular fitness later in life. However, our results could be in agreement with other perinatal factors, because birth weight has been

TABLE 2 Characteristics of the study sample in the perinatal period and during adolescence[1]

	All, n = 2567	Boys, n = 1141	Girls, n = 1426	Duration of any breastfeeding Never	<3 mo	3–5 mo	≥6 mo
Perinatal characteristics							
Birth weight, *kg*	3.4 ± 0.5	3.4 ± 0.5	3.3 ± 0.5*	3.3 ± 0.6	3.3 ± 0.5	3.4 ± 0.5	3.4 ± 0.5*
Duration of any breastfeeding, *mo*	3.0 (1.0, 6.0)	3.0 (1.0, 6.0)	3.0 (1.0, 6.0)	0 (0, 0)	2.0 (1.0, 2.0)	3.0 (3.0, 4.0)	8.0 (6.0, 12.0)*
Any breastfeeding ≥ 6 mo, *%*	28.1	27.7	28.5	0	0	0	100*
Adolescent characteristics							
Age, *y*	14.9 ± 1.2	14.9 ± 1.2	14.9 ± 1.2	14.9 ± 1.2	14.9 ± 1.2	14.9 ± 1.2	14.9 ± 1.2
Sexual maturation stages I, II, III, IV, V, *%*	0, 5, 19, 42, 33	1, 8, 21, 39, 31	0, 3, 19, 44, 34*	0, 6, 20, 40, 34	1, 5, 18, 42, 34	0, 4, 17, 41, 38	1, 5, 20, 44, 30
Weight, *kg*	59.3 ± 12.5	63.0 ± 14.1	56.7 ± 10.3*	59.4 ± 13.1	59.8 ± 12.7	60.1 ± 13.1	58.8 ± 11.6
Height, *cm*	166.2 ± 9.1	170.8 ± 9.5	162.5 ± 6.7*	165.1 ± 8.8	165.9 ± 8.9	166.6 ± 9.2	166.9 ± 9.2*
BMI, kg/m^2	21.4 ± 3.7	21.5 ± 3.9	21.4 ± 3.5	21.7 ± 4.0	21.6 ± 3.7	21.6 ± 3.8	21.0 ± 3.4*
20m shuttle run, *stage*	5.0 ± 2.7	6.5 ± 2.7	3.8 ± 1.9*	4.9 ± 2.6	4.8 ± 2.5	5.2 ± 2.8	5.1 ± 2.7
Handgrip strength, *kg*	30.8 ± 8.8	36.6 ± 9.2	26.1 ± 4.8*	30.3 ± 8.7	30.5 ± 8.9	30.9 ± 8.6	31.3 ± 9.0
Standing long jump, *cm*	163.4 ± 35.4	185.9 ± 32.1	145.1 ± 26.2*	154.4 ± 32.3	160.8 ± 35.7	165.6 ± 34.9	170.0 ± 36.0*

[1] Data are shown as mean ± SD, median (25th,75th percentile), or percentage. *$P < 0.05$ for difference between genders or breastfeeding categories, analyzed by ANOVA or chi-square test.

positively associated with muscular fitness during adolescence (32). Muscular fitness is clearly influenced by morphological factors such as cross-sectional muscle area or fat-free mass content (33). For that reason, in the present study, fat mass and fat-free mass were used as confounders to adjust for body composition differences. Furthermore, we performed additional analyses to test whether differences in these morphological factors could affect the association observed between breastfeeding and lower body explosive strength. Our results suggest that longer breastfeeding is significantly associated with higher performance in the standing long jump test in adolescents with either high or low fat mass, fat-free mass, and height. We also analyzed if longer breastfeeding duration was associated with higher fat-free mass, which could explain the increase in lower body explosive strength, but there was no such association (data not shown). Collectively, these findings suggest that breastfeeding could specifically affect lower body explosive strength independently of whole body morphological factors.

It is well established that probably all living beings are characterized by specific growth rates in the different parts composing the organism, which is called allometric growth (34). Studies on animals have suggested an early prenatal acceleration of growth in those muscles required for locomotion (35). In humans, although upright locomotion appears when the child is ~1 y old, a stepping pattern is present already at birth or shortly after (36). Therefore, it is reasonable to think that the feeding pattern during the first months and years of life could influence the development of the lower body. Given the benefits associated with a higher muscular fitness both in youth (37) and adulthood (11), any modifiable pattern able to increase muscular fitness will be of high interest from a public health perspective. Further studies should analyze whether the different results observed for the standing long jump and handgrip strength are due to the different muscle groups involved (lower body vs. upper body) or to the type of muscle effort (a maximum, dynamic contraction in a short period of time vs. a maximum isometric contraction).

In this study, the duration of any breastfeeding was also significantly associated with cardiorespiratory fitness in girls. However, this association did not show a clear direction and disappeared when exclusive breastfeeding was considered. Only 1 previous study has examined the association of breastfeeding with cardiorespiratory fitness in youth (5). In that study, whether an individual had been breastfed or not and duration of breastfeeding were not associated with cardiorespiratory fitness measured by a cycling test in 9-y-old children (5). Despite the methodological differences between the 2 studies, our results

TABLE 3 Physical fitness characteristics according to duration of any breastfeeding[1]

	n	Duration of any breastfeeding Never	<3 mo	3–5 mo	≥6 mo	P-value
Boys						
20-m shuttle run, *stage*	755	7.1 (6.7, 7.5)	6.5 (6.2, 6.8)	6.7 (6.4, 7.1)	6.6 (6.3, 6.9)	0.184
Handgrip strength, *kg*	856	36.0 (35.1, 36.9)	35.8 (35.2, 36.5)	35.8 (35.1, 36.5)	36.6 (36.0, 37.3)	0.238
Standing long jump, *cm*	851	180.1 (176.0, 184.3)[c]	184.4 (181.4, 187.3)[bc]	186.4 (183.3, 189.5)[b]	191.0 (188.1, 193.9)[a]	<0.001
Girls						
20-m shuttle run, *stage*	965	4.2 (3.9, 4.4)[a]	3.6 (3.4, 3.8)[c]	4.0 (3.8, 4.2)[ab]	3.7 (3.6, 3.9)[bc]	0.003
Handgrip strength, *kg*	1126	26.0 (25.5, 26.5)	25.7 (25.3, 26.2)	26.3 (25.8, 26.8)	26.4 (26.0, 26.8)	0.138
Standing long jump, *cm*	1114	142.9 (139.8, 146.0)[c]	144.4 (141.9, 146.9)[bc]	147.3 (144.5, 150.1)[ab]	150.2 (147.7, 152.6)[a]	<0.001

[1] Results expressed as estimated mean (95% CI). P-values obtained from ANCOVA. Confounders: gestational age, birth weight, current age, fat mass, fat-free mass, maternal education, parental weight status, country, number of cigarettes per week, and days of vigorous physical activity per week. Means in a row with superscripts without a common letter differ, $P < 0.05$.

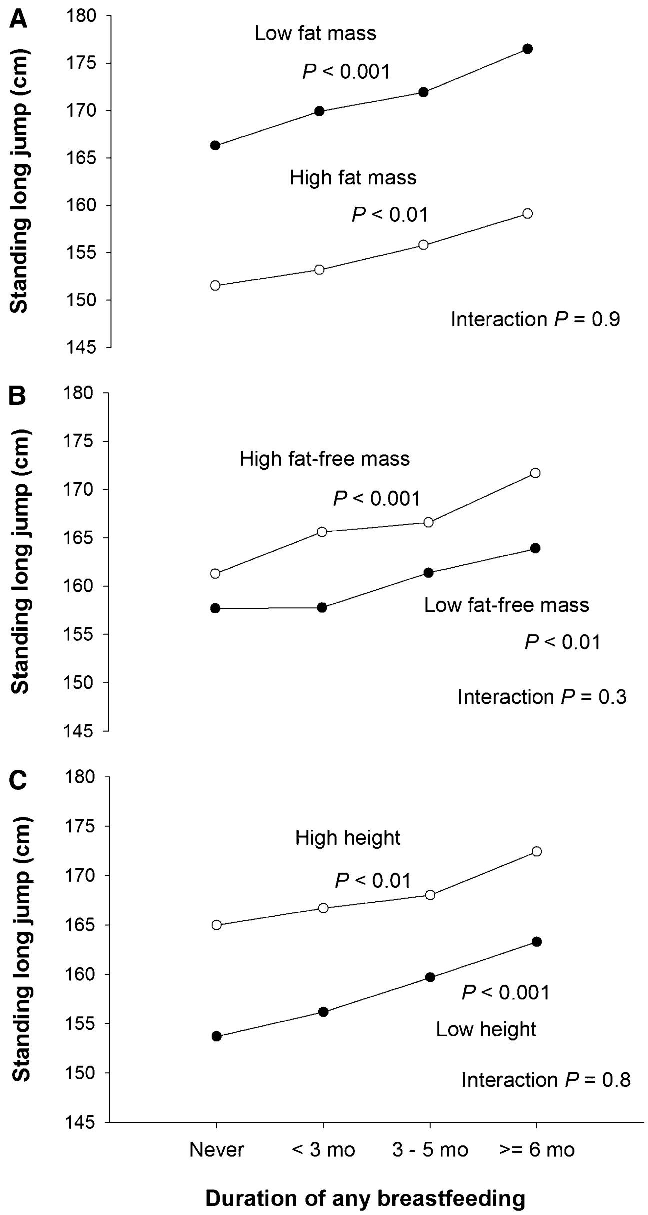

FIGURE 1 Standing long jump performance by duration of any breastfeeding according to fat mass (*A*), fat-free mass (*B*), and height (*C*). Data points indicate estimated mean, $n = 1965$. The set of confounders was gender, gestational age, birth weight, current age, fat mass (except in *A*), fat-free mass (except in *B*), maternal education, parental weight status, country, number of cigarettes per week, and days of vigorous physical activity. *P*-values for the interactions breastfeeding × fat mass (*A*), breastfeeding × fat-free mass (*B*), and breastfeeding × height (*C*) in relation to standing long jump performance were also calculated.

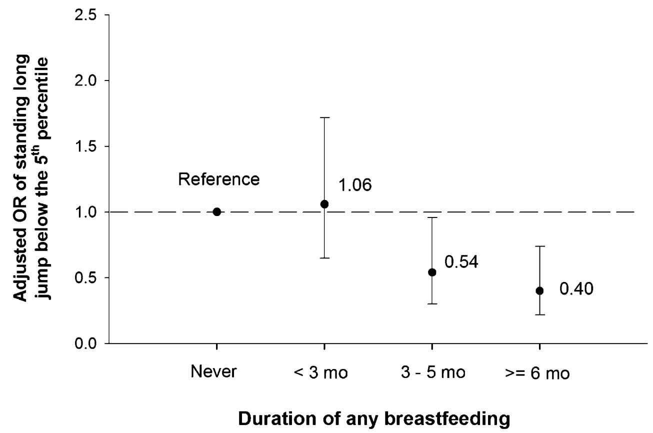

FIGURE 2 OR of having a standing long jump performance below the 5th percentile (14) according to the breastfeeding category after adjustment for gender, age, and country. Error bars represent 95% CI, $n = 2414$.

and those of the other study support the lack of a consistent association between breastfeeding duration and later cardiorespiratory fitness.

The exposure variables used in the present study, i.e. duration of any and exclusive breastfeeding, were assessed by means of maternal recall collected retrospectively some years postpartum. The ideal study design would be to assess breastfeeding patterns prospectively from birth and follow children over time, but the considerable expense and effort required would rule out this approach for many investigators. Because of the practical advantages of a shortened study period and relative ease of obtaining data, a retrospective approach is often used to collect breastfeeding data by maternal recall (38). Several articles have suggested this procedure as a valid and reliable measure of children's infant feeding habits (39). Overall, mothers seem to recall accurately the duration of any breastfeeding, while the recall of the age at introducing foods and fluids other than breast milk seems to be less accurate (39). For a higher certainty, we repeated the analyses using either any or exclusive breastfeeding, and the results for lower body muscular fitness were consistent.

The fitness tests used in the HELENA Study were selected based on the scientific evidence from previous studies (17). During the last decades, numerous field tests have been developed to measure muscular fitness in children and adolescents (19). The handgrip strength and standing long jump have shown a good criterion-related validity compared with laboratory tests of upper and lower body strength (40), which suggests the role of these tests as appropriate measures of muscular fitness (41).

One of the greatest advantages of the HELENA Study was the strict standardization of the field work, which precludes to a great extent the kind of immeasurable confounding bias that often interferes when comparing results from isolated studies (13). Standard operational manuals were designed and thoroughly checked. In addition, a workshop training week was conducted with all researchers involved in the field work. And finally, the feasibility and safety of measurements and tests, as well as the necessary logistics, were tested in a pilot study prior to the data collection (13). The reliability of anthropometric and fitness techniques was carefully analyzed. All skinfolds presented intra-observer technical error of measurements < 1 mm and intra-observer reliability values > 95% (23). No significant differences were observed between test and retest in any of the fitness measurements, with all bias (test-retest difference) close to 0 and no heteroscedasticity pattern (18).

Our analyses have used the detailed information available on individual and family characteristics to adjust for factors that potentially confound the relationship of breastfeeding with health status later in life: gestational age, birth weight, body composition, socioeconomic status, parental weight status, and the adolescent's smoking behavior and physical activity (6). However, we cannot exclude the possibility of residual confounding, because some confounders could have been measured more effectively (e.g. maternal education and parental weight status were reported by the adolescents), and other important confounders, such as maternal smoking or maternal weight change during gestation, were not available. Prospective and intervention studies to effectively promote breastfeeding (42) could provide more robust conclusions on the effects of breastfeeding on later physical fitness.

In conclusion, we have found a positive association between breastfeeding duration and lower body explosive strength during adolescence. These findings suggest a role of early infant feeding patterns in determining muscular fitness later in life, supporting the continued promotion of breastfeeding.

Acknowledgments

Members of the HELENA Study Group are as follows: From the Universidad de Zaragoza (Spain): L. A. Moreno, J. Fleta, J. A. Casajús, G. Rodríguez, C. Tomás, M. I. Mesana, G. Vicente-Rodríguez, A. Villarroya, C. M. Gil, I. Ara, J. Revenga, C. Lachen, J. Fernández Alvira, G. Bueno, A. Lázaro, O. Bueno, J. F. León, J. Garagorri, M. Bueno, J. P. Rey López, I. Iglesia, P. Velasco, and S. Bel. From the Consejo Superior de Investigaciones Científicas (Spain): A. Marcos, J. Wärnberg, E. Nova, S. Gómez, E. Ligia Díaz, J. Romeo, A. Veses, M. A. Puertollano, B. Zapatera, T. Pozo, and D. Martinez-Gomez. From the Université de Lille 2 (France): L. Beghin, C. Libersa, F. Gottrand, C. Iliescu, and J. Von Berlepsch. From the Research Institute of Child Nutrition Dortmund, Rheinische Friedrich-Wilhelms-Universität Bonn (Germany): M. Kersting, W. Sichert-Hellert, and E. Koeppen. From the University of Pécs (Hungary): D. Molnar, E. Erhardt, K. Csernus, K. Török, S. Bokor, Mrs. Angster, E. Nagy, O. Kovács, and J. Répasi. From the University of Crete School of Medicine (Greece): A. Kafatos, C. Codrington, M. Plada, A. Papadaki, K. Sarri, A. Viskadourou, C. Hatzis, M. Kiriakakis, G. Tsibinos, C. Vardavas Manolis Sbokos, E. Protoyeraki, and M. Fasoulaki. From the Institut für Ernährungs- und Lebensmittelwissenschaften –Ernährungphysiologie. Rheinische Friedrich Wilhelms Universität (Germany): P. Stehle, K. Pietrzik, M. González-Gross, C. Breidenassel, A. Spinneker, J- Al-Tahan, M. Segoviano, A. Berchtold, C. Bierschbach, E. Blatzheim, A. Schuch, and P. Pickert. From the University of Granada (Spain): M. J. Castillo Garzón, Á. Gutiérrez Sáinz, F. B. Ortega Porcel, J. Ruiz Ruiz, E. G. Artero, V. España-Romero, D. Jiménez Pavón, P. Chillón, Virginia Aparicio, A. Carbonell. From the Istituto Nazionalen di Ricerca per gli Alimenti e la Nutrizione (Italy): D. Arcella, G. Catasta, L. Censi, D. Ciarapica, M. Ferrari, C. Le Donne, C. Leclerq, L. Magrì, G. Maiani, R. Piccinelli, A. Polito, R. Spada, and E. Toti. From the University of Napoli "Federico II" Dept of Food Science (Italy): L. Scalfi, P. Vitaglione, and C. Montagnese. From the Ghent University (Belgium): I. De Bourdeaudhuij, S. De Henauw, T. De Vriendt, L. Maes, C. Matthys, C. Vereecken, M. de Maeyer, C. Ottevaere, and I. Huybrechts. From the Medical University of Vienna (Austria): K. Widhalm, K. Phillipp, S. Dietrich, B. Kubelka, and M. Boriss-Riedl. From the Harokopio University (Greece): Y. Manios, E. Grammatikaki, Z. Bouloubasi, T. Louisa Cook, S. Eleutheriou, O. Consta, G. Moschonis, I. Katsaroli, G. Kraniou, S. Papoutsou, D. Keke, I. Petraki, E. Bellou, S. Tanagra, K. Kallianoti, D. Argyropoulou, K. Kondaki, S. Tsikrika, and C. Karaiskos. From the Institut Pasteur de Lille (France): J. Dallongeville and A. Meirhaeghe. From the Karolinska Institutet (Sweden): M. Sjöstrom, P. Bergman, M. Hagströmer, L. Hallström, M. Hallberg, E. Poortvliet, J. Wärnberg, N. Rizzo, L. Beckman, A. Hurtig Wennlöf, E. Patterson, L. Kwak, L. Cernerud, P. Tillgren, and S. Sörensen. From the Asociación de Investigación de la Industria Agroalimentaria (Spain): J. Sánchez-Molero, E. Picó, M. Navarro, B. Viadel, J. Enrique Carreres, G. Merino, R. Sanjuán, M. Lorente, M. J. Sánchez, and S. Castelló. From Campden BRI (United Kingdom): C. Gilbert, S. Thomas, E. Allchurch, and P. Burguess. From the SIK –Institutet foer Livsmedel och Bioteknik (Sweden): G. Hall, A. Astrom, A. Sverkén, and A. Broberg. From the Meurice Recherche and Development asbl (Belgium): A. Masson, C. Lehoux, P. Brabant, P. Pate, and L. Fontaine. From the Campden and Chorleywood Food Development Institute (Hungary): A. Sebok, T. Kuti, and A. Hegyi. From Productos Aditivos SA (Spain): C. Maldonado and A. Llorente. From Cárnicas Serrano SL (Spain): E. García. From Cederroth International AB (Sweden): H. von Fircks, M. Lilja Hallberg, and M. Messerer. From Lantmännen Food R&D (Sweden): M. Larsson, H. Fredriksson, V. Adamsson, and I. Börjesson. From the European Food Information Council (Belgium): L. Fernández, L. Smillie, and J. Wills. From the Universidad Politécnica de Madrid (Spain): M. González-Gross, A. Meléndez, P. J. Benito, J. Calderón, D. Jiménez-Pavón, J. Valtueña, P. Navarro, A. Urzanqui, U. Albers, R. Pedrero, and J. J. Gómez Lorente. E.G.A. and S.D.W. conceived the hypothesis; E.G.A. conducted the statistical analyses and drafted the manuscript; F.O.P. provided statistical advice and supervised all the analyses; E.G.A., S.D.H., F.O.P., V.E.R., I.L., I.H., L.M.A., and M.J.C. contributed to the interpretation and discussion of the results; Y.M., D.M., L.A.M., M.S., F.G., M.J.C., and S.D.H. contributed to the concept and design of the HELENA Study; and A.P., B.M., K.W., M.K., Y.M., D.M., L.A.M., M.S., F.G., and S.D.H. collected the data. All authors critically revised the draft and approved the final manuscript.

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