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ORIGINAL RESEARCH

Association of Physical Fitness and Anthropometric Parameters With Lung Function in 7-Year-Old Children

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Purpose: Associations between health-related parameters and lung function remain unclear in childhood. The study aims to evaluate the relationship between physical fitness and anthropometric parameters with the lung function of healthy scholar-aged children. ***Method***: A total of 418 children aged 7 years old participated in this study. The associations of physical fitness (handgrip strength, standing broad jump, and 800-m run) and anthropometric (waist circumference and body mass index) parameters with lung function (forced vital capacity and forced expiratory volume in 1 s) were analyzed using a mixed-linear regression model. ***Results:*** Girls had significantly lower forced vital capacity values ($P = .006$) and physical fitness ($P < .030$) compared to boys. On mixed-linear regression analyses, waist circumference ($P = .003$) was independently associated with forced vital capacity, explaining 34.6% of its variance, while handgrip strength ($P = .042$) and waist circumference ($P = .010$) were independently associated with forced expiratory volume in 1 second, accounting together for 26.5% of its variance in 7-year-old healthy children. ***Conclusions***: Handgrip strength and waist circumference were associated with lung function in healthy children highlighting the influence of upper body muscular strength and trunk dimension on lung function. Our results corroborate the need to promote physical fitness during childhood to protect against lung complications in later on in life.

Q2 Q1

Keywords: respiratory system, handgrip strength, body composition

Key Points

- Handgrip strength and waist circumference are associated with lung function in healthy children highlighting the influence of upper body muscular strength and thoracic dimension.
- A longitudinal study should be designed to study the evolution of lung parameters and the potential role of physical fitness and anthropometric characteristics during growth development.

Lung structure and respiratory function can be considered structural parameters which may be difficult to remodel during life. Physical exercise is an effective intervention in preventing and treating childhood obesity due to the well-known physiological adjustment response in the cardiovascular, musculoskeletal, and hematological systems (18). However, the structural and functional properties of the lungs do not respond to exercise to the same extent (24).

Muscular and cardiorespiratory fitness (CRF) are 2 important health-related components of physical fitness, and both have been reported to be associated with all-cause mortality (12). To the best of our knowledge, there is limited evidence of physical fitness being associated with elevated lung function during childhood (13). In adults, positive associations have been described between lung function and CRF (6). Consistently, physical inactivity has been shown to reduce lung function, whereas participation in vigorous physical activity has been associated with higher values of forced expiratory volume in 1 second (FEV_1) in the adult population (17). In the elderly population, handgrip strength has shown a consistent correlation with forced vital capacity (FVC) and FEV_1. Concerning childhood, this relationship is not well studied, and it is still unknown whether physical fitness has a relevant influence on lung function (13). Body mass, muscular strength, and thoracic extension can play a conflicting role in child's lung function. While muscular strength and body growth increase lung volume, adiposity and thoracic stiffness decrease it. Some studies have described that lung function is associated with handgrip strength in adolescents (25,34), but the link between physical fitness parameters and lung function is still uncertain in prepubertal healthy children.

Meanwhile, the prevalence of obesity in children is increasing globally (20). Excessive body mass at a young age is likely to persist into adulthood and is associated with physical and psychosocial comorbidities (22). However, the association of body composition with lung function is still poorly understood, although there are a few more available studies compared with physical

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Q4 Q3

fitness. While body mass index (BMI) and waist circumference (WC) have been associated with lower lung function in adults (35), previous research in children with obesity suggested a positive correlation between BMI and lung function (4,7,14). These equivocal findings of the effect of the anthropometric parameters on respiratory function in children explain the current investigation of the association between physical fitness and anthropometric parameters in a uniform population of prepubertal children.

The objectives of the present study were aimed to evaluate the associations of (1) physical fitness parameters, such as upper body muscular strength, lower limb explosive strength, and CRF and (2) anthropometric parameters, such as WC and BMI, with lung function parameters of 7-year-old healthy children by assessing FVC and FEV_1. An integral analysis of the influence of physical fitness and anthropometric parameters on lung function during childhood may help to understand the potential plasticity of lung function in early life as well as decipher meaningful childhood physiology processes.

Materials and Methods

Participants

A total of 418 school-aged children (207 girls and 211 boys) were included in the study. Participants were recruited from schools in Cassà de la Selva, Palamós, and Salt, all of them in Girona (northern Spain). From the 418 participants, children with missing information on lung function, physical fitness, or anthropometric parameters were excluded from the mixed-linear regression analysis. This resulted in a mixed-linear regression analysis with 310 children for the FVC and 283 children for the FEV_1.

The inclusion criteria at baseline were (1) to be aged between 7 and 8 years old and (2) to be healthy children. The exclusion criteria were as follows: (1) major congenital abnormalities, (2) chronic illness or chronic medication use, (3) musculoskeletal or neurological disease, (4) functional limitations, (5) the inability to perform the spirometric maneuver according to the American Thoracic Society/European Respiratory Society guidelines in children (5), and/or (f) the ratio FEV_1/FVC lower than 70%.

A cross-sectional observational study was designed. The Institutional Review Board of *(blinded)* Hospital approved the research (Code Competencia motricitat and PEHC-Palamos_ 2022.129), which confirmed the application of the recommendations of the Declaration of Helsinki. Informed consent was obtained from the parents together with the assent from their children.

Lung Function Testing

To assess lung function, objective parameters of respiratory function, such as FVC and FEV_1 were measured in accordance with the American Thoracic Society/European Respiratory Society guidelines in children (5). Measurements of lung function were assessed using a validated spirometer (In2itive Vitalograph) by a skilled technician with extensive experience in pediatric respiratory research and data collection. Subjects did a forced expiration maneuver in a sitting position. Forced flow volume tests were performed until 3 reproducible loops were achieved. The results were rated as valid only if the degree of quality was grade A, that is, minimum of 3 acceptable attempts and difference of the 2 best (FVC and FEV_1) values ≤100 mm. The reference values for FVC and FEV1 were described following the Global Lung Initiative (27).

Physical Fitness Parameters

A handgrip strength test was performed to evaluate the upper body's muscular strength. The test consisted of squeezing an analog hand dynamometer (TKK 5001, Grip-A, Takei) gradually and continuously for at least 5 seconds. The grip span was standardized at 5.0 cm. The test was performed twice for each hand, recording the highest value for each one. In the end, the average of these 2 bilateral results was used for the posterior analyses.

The standing broad jump was performed to assess lower limb explosive strength. Children jumped as far as possible with their feet together while remaining upright. The better distance of 2 attempts was used in the analyses.

The handgrip strength and standing broad jump adjustment to standard deviation score were standardized according to age- and sex-adjusted values from regional normative data (16).

An 800-m run test was performed to assess CRF. The objective of this test was to complete an 800-m track, around 2 cones 40 m apart, in the quickest possible time. The total time to perform the goal was recorded in minutes and seconds.

Anthropometric Parameters

WC was measured in the standing position at the umbilical level in centimeters. Body weight was measured wearing light clothes and collected under fasting conditions with a bioelectrical impedance device (Portable TANITA; 240MA) with the empty bladder. Body height was measured using a wall-mounted stadiometer (SECA SE206) in centimeters. The BMI for each participant was calculated as weight divided by height square (in kilograms per meter squared).

The WC and BMI adjustment to standard deviation score were standardized according to age- and sex-adjusted values from regional normative data (36).

Statistical Analyses

Student's *t* tests were performed to compare mean values of lung function, physical fitness, and anthropometric parameters between the sexes. Kolmogorov–Smirnov tests were used to evaluate normal distribution, and Levene's test to evaluate the homogeneity of variances. In case of neglecting these assumptions, comparisons between groups were examined using nonparametric Mann–Whitney *U* tests for continuous values, which was the case for FVC and FEV_1.

The association between lung function, physical fitness, and anthropometric parameters described in the previous section was explored using Pearson linear regression analyses. These were conducted separately for girls and boys. The variables with a P value $< .05$ in the univariate analyses were included in the posterior multivariate linear regression analyses. Subsequent mixed-linear regression analyses using the enter method were applied to analyze the relationship of lung function (FVC and FEV_1) as the dependent parameters, and physical fitness and anthropometric (handgrip strength, WC, and BMI) as the main independent ones. All the analyses were undertaken using SPSS software (version 25.0).

Results

Table 1 shows the description of the lung function, physical fitness, and anthropometric parameters of the study sample. Girls had significantly lower FVC values compared with boys (–4.8%;

$P = .006$). Regarding physical fitness, girls had significantly lower strength scores in handgrip strength (−5.3%; $P = .030$), lower standing broad jump values (−9.4%; $P < .001$), and slower scores in endurance 800-m test (+7.3%; $P < .001$) compared with boys. Regarding anthropometric parameters, no significant differences were found in WC and BMI between the sexes.

Pearson linear regression analyses of lung function parameters (FVC and FEV_1) with physical fitness and anthropometric parameters are displayed in Figures 1 and 2, respectively. FVC was significantly associated with handgrip strength (girls: $r = .310$; $P < .001$; boys: $r = .343$; $P < .001$), WC (girls: $r = .394$; $P < .001$; boys: $r = .420$; $P < .001$), and BMI (girls: $r = .339$; $P < .001$; boys: $r = .332$; $P < .001$).

In a similar pattern, FEV_1 correlated positively with handgrip strength (girls: $r = .329$; $P < .001$; boys: $r = .326$; $P < .001$), WC (girls: $r = .334$; $P < .001$; boys: $r = .387$; $P < .001$), and BMI (girls: $r = .246$; $P < .001$; boys: $r = .349$; $P < .01$). In contrast, FVC and FEV_1 were not significantly associated with standing broad jump and 800-m run, neither in girls nor in boys.

Mixed-linear regression analyses are shown in Table 2 to adjust for confounding variables such as sex and height. On the first multivariate analysis using FVC as a dependent factor, WC was independently associated with FVC, explaining 34.6% of its variability. Using FEV_1 as the dependent factor, handgrip strength and WC were independently associated with FEV_1, explaining all together 26.5% of its variability.

Table 1 Characteristics of the Lung Function, Physical Fitness, and Anthropometric Parameters of the School-Aged 7-Year-Old Participants Described by Sex

	Total	N	Girls	n	Boys	n	*P*
Lung function parameters							
FVC, L·min^{-1}	1.64 (0.28)	338	1.59 (0.27)	167	1.68 (0.28)	171	**.006**
FVC, *%-reference*	99.75 (16.3)	338	101.15 (16.47)	167	98.38 (16.32)	171	–
FEV_1, L·min^{-1}	1.44 (0.26)	309	1.42 (0.25)	153	1.46 (0.28)	156	.269
FEV_1, *%-reference*	98.29 (17.2)	309	99.63 (16.33)	153	96.99 (17.92)	156	–
Physical fitness parameters							
Handgrip strength, kg	21.25 (4.96)	387	20.63 (4.97)	192	21.84 (4.88)	195	**.030**
Handgrip strength, SDS	0.54 (1.15)	387	0.54 (1.20)	192	0.53 (1.09)	195	*.948*
Standing broad jump, cm	97.66 (17.50)	325	92.72 (15.53)	158	102.34 (18.01)	167	**<.001**
Standing broad jump, SDS	−0.35 (0.90)	325	−0.41 (0.87)	169	−0.28 (0.92)	160	*.196*
800-m run, s	313.76 (52.54)	276	326.11 (46.96)	131	302.61 (54.93)	145	**<.001**
Anthropometric parameters							
WC, cm	57.91 (6.75)	395	57.75 (6.94)	196	58.08 (6.58)	199	.399
WC, SDS	−0.20 (0.98)	395	−0.17 (1.03)	196	−0.23 (0.94)	199	*.537*
BMI, kg/m^2	16.42 (2.58)	393	16.39 (2.80)	194	16.45 (2.36)	199	.724
BMI, SDS	−0.21 (0.96)	393	−0.19 (0.99)	194	−0.23 (0.94)	199	*.443*

Abbreviations: BMI, body mass index; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 second; SDS, standard deviation score; WC, waist circumference. Data are shown in mean (SD). Values for comparison between sexes were estimated by Student *t* test for physical fitness and anthropometric parameters and by Mann–Whitney *U* test for lung function parameters according to normality assumptions. Significant differences ($P < .05$) are marked in bold.

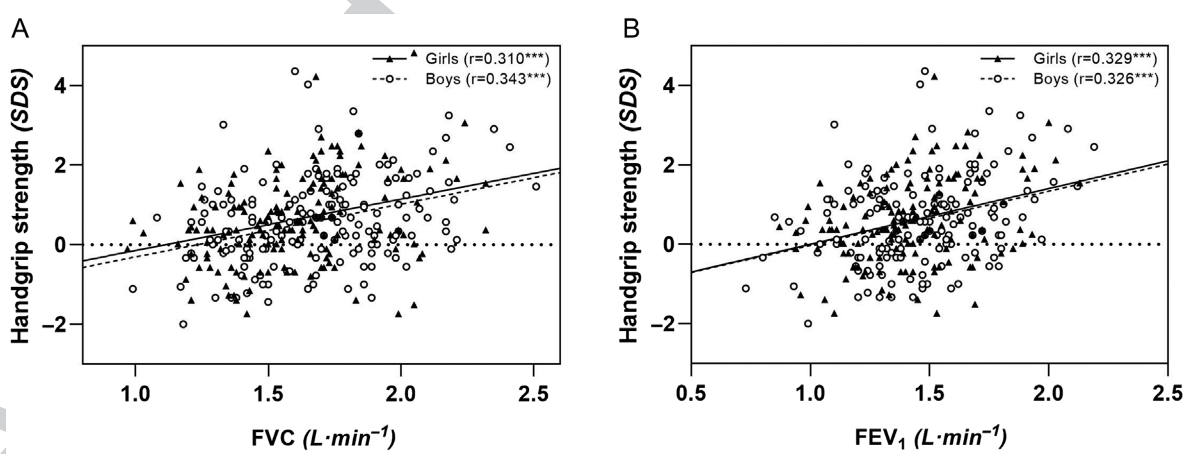

Figure 1 — Scatter plots for (A) FVC and (B) FEV_1 with children's handgrip strength (n = 326, and n = 296, respectively). Black triangles and continuous lines depict girls, whereas white dots and discontinuous lines depict boys. Significant values (***) indicate $P < .001$ from Pearson correlation. FEV_1 indicates forced expiratory volume in 1 second; FVC, forced vital capacity.

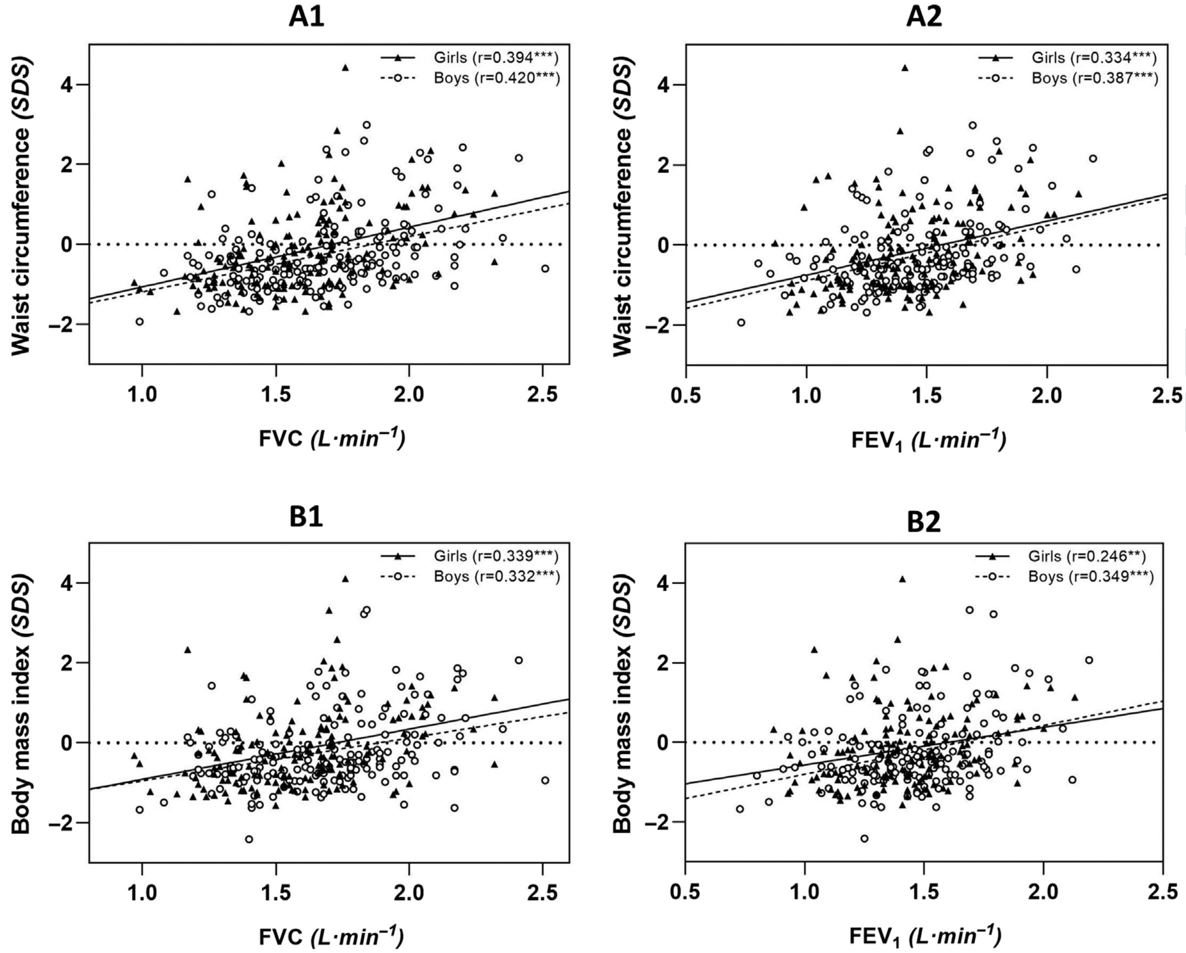

Figure 2 — Scatter plots for (A) FVC and (B) FEV_1 with children's WC (n = 332, and n = 296) and children's BMI (n = 323, and n = 294). Black triangles and continuous lines depict girls, whereas white dots and discontinuous lines depict boys. Significant values (**) indicate $P < .01$ and (***) indicate $P < .001$ from Pearson correlation. BMI indicates body mass index; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; SDS, standard deviation score; WC, waist circumference.

Table 2 Mixed-linear Regression Analyses for FVC (n = 310) and FEV_1 (n = 283) as Dependent Variables, and Sex, Age, Height, Handgrip Strength, WC, and BMI, as Independent Variables

	FVC		FEV_1	
	B	*P*	*β*	*P*
Sex	−0.166	**.000**	−0.076	.139
Height, *SDS*	0.412	**.000**	0.325	**.000**
Handgrip strength, *SDS*	0.079	.133	0.117	**.042**
WC, *SDS*	0.263	**.003**	0.274	**.010**
BMI, *SDS*	−0.081	.351	−0.088	.393
Total R^2	.346		.265	

Abbreviations: BMI, body mass index; FVC, forced ventilatory capacity; FEV_1, forced expiratory volume in 1 second; SDS, standard deviation score; WC, waist circumference. Significant differences ($P < .05$) are marked in bold.

Discussion

The main findings of the present study showed that both handgrip strength and WC were positively and significantly associated with lung function in 7-year-old healthy children. Another noteworthy finding was that girls of this age group had significantly lower FVC values, scored lower with regard to handgrip strength and standing broad jump, and displayed a lower endurance 800-m test, in comparison to boys of the same age category.

Physical fitness (ie, muscle strength) has been thought to be related to lung function, due to the contribution of respiratory muscle strength to the forced maneuvers involved in the measurement of lung function parameters (29). Our results showed that children have a positive association between handgrip strength and lung function, while lower limb explosive strength and CRF parameters did not correlate with any of the studied parameters of lung function. Handgrip strength has been associated with a range of health-related outcomes, including respiratory diseases in adults (6). The decline in mobility with aging may be caused by decreases in both muscle strength and power, but also due to decreases in spirometric pulmonary function (33). Kanai et al (19) showed that decreased handgrip strength can predict lung function impairment in male workers. Concerning the children population, Latorre-Román et al (21) reported a significant improvement in FEV_1, and upper and lower body strength after 12 weeks of an intermittent training program in 11-year-old children with asthma. According to our findings, Smith et al (34) found a correlation between handgrip strength and lung function in a cohort of 1846 healthy adolescents. In that respect, associations between physical fitness and respiratory function seem to be mediated through effects on ventilatory muscle strength (17).

CRF has been also shown to be positively correlated with lung function in adults (8). In a similar study, Köchli et al (20) showed that CRF, via 20-m shuttle test, was independently associated with higher lung function parameters in 7-year-old children. Compared with our data, the different results found by Köchli et al could be explained by their higher sample size, including a higher sample of children with overweight and obesity. Hancox and Rasmussen (13) also showed that healthy children and young adults (9–38 y old) had a modest positive association between CRF and lung function. These latter authors observed that improvements in physical fitness during childhood and adolescence were associated with growth in lung volumes, while no longitudinal associations were found after peak adult lung function. In contrast with the reviewed literature, our results showed a lack of association between CRF and lung function. The observed differences could be affected by the exclusive participation of healthy prepubertal children in a cross-sectional study. The absence of hormonal influence produced by puberty in physical characteristics may reduce this association, as has been described in airway size (28). Furthermore, activity type may be important in determining the size or direction of the association between physical fitness and lung function: some sports, specifically aquatic sports, are associated with increased lung diffusion and lung volume, while other types of activities have shown no influence (10,23).

As far as sex differences are concerned, girls had lower values in FVC, handgrip strength, standing broad jump, and 800-m compared with boys in the sample of school-aged children. Females have smaller lung volumes and a lower diffusion capacity (32), which may lead women to be more susceptible to lung dysfunction. However, Ripoll et al (28) found no sex differences in the cross-sectional airway area of young participants (<13 y), indicating that the sex differences in airway size are not innate, but rather associated with posterior hormonal changes from puberty. In our study, lung function was significantly correlated with handgrip strength and body composition, which indicates the relevance of muscular strength in the study of sex differences in prepubertal children. It is well accepted that exercise has the potential to improve the smooth muscle function of bronchia and, thereby, improve lung function in overweight children (9). Moreover, exercise may beneficially affect the elastic properties of lungs and airways, which enhance airway flow and consequently FEV_1 (20). Therefore, increasing physical fitness is highly recommended at an early age, specifically in girls, due to the positive long-term effects on respiratory health.

Nowadays, low levels of physical fitness are predominant in both children and adults, leading to high indexes of sedentarism and obesity (20). This widespread disorder prompts an impairment of respiratory function and structure in adults leading to physiologic and pathophysiologic complications. This may be the result of increased stiffness of the thoracic cage due to the accumulation of fat tissue around the area (17). Rowe et al (30) and Steele et al (35) already showed that high measures of anthropometric parameters (WC and BMI) were associated with lower lung function in adults. In this sense, abdominal adiposity may be particularly detrimental to lung function compared with BMI among adults (35).

Concerning prepubertal children, this negative association between body composition and lung function has not been observed in the literature. The increase in thoracic space in children seems to have a positive association between BMI and lung function (4,7,14), being aligned with the results presented in our study. Chen et al (7) showed that WC was associated with lung function in 718 children of 6–17 years, while Hu et al (14) showed a similar association in a sample of 2179 children of 8–13 years of age. In contrast, Köchli et al (20) found that school-aged 7-year-old children with overweight and obesity had decreased lung function parameters in a cohort of 1246 participants. A higher BMI has been related to a higher risk for children's respiratory symptoms and diseases (14), and childhood obesity may also provoke an imbalance between ventilation and airway flow (20). In our study, WC was the only anthropometric parameter associated with lung function in the mixed-linear analysis, probably indicating the relevance of higher thoracic dimension. Therefore, the analysis of the chest circumference should be examined in future studies with healthy children, as it has been associated with lung function in other populations (1). To summarize, the adverse effects provoked by an excess of body mass on lung function seem to not be manifested during early life, although a higher risk for children's respiratory symptoms is already presented (14).

The unexpected positive association between WC and lung function could be hypothetically explained as a result of body and thoracic growth differences and larger muscles influencing the presented increases in FVC and FEV_1 (26). What appears to be clear is that higher lung function is not enough to compensate for the augmented metabolic requirements of an overweight person in future adult life. Thus, 2 conflicting mechanisms are influencing the link between lung function and body size: while growth increases lung volume, adiposity, and thoracic stiffness decrease it. Probably only obese children, and not children with moderate overweight, would show a decrease in lung volume due to a higher fat mass canceling out the increase of lung function while increasing growth (3). Further research is required to provide evidence of whether weight gain during childhood could be also a predictor of lung function later in life.

Childhood has been described as a sensitive period to instigate physiological and particularly pulmonary modifications in humans. Barker and Osmond (2) hypothesized that a vulnerable prenatal or early postnatal environment would predispose individuals to later chronic lung disease. The rib cage reaches its final dimensions upon complete epiphyseal closure at somatic maturation; then, lung growth seems to be possible only during childhood before puberty when space is made available to accommodate the new structures

(15). In conclusion, our results reinforce the need to increase physical fitness in children, especially girls, to improve lung function as a protective factor against future pulmonary complications.

Strengths and Limitations

Well-known limitations arise from our cross-sectional design. This study is associative, and thus, no differentiation in terms of causality can be made. During childhood, the development of the lungs is characterized by alveolar enlargement, peripheral airway elongation, and both elongation and enlargement of the central airways (31). These functional changes may be influenced by genetically predisposed strength and anthropometric settings which should be better evaluated in a longitudinal study, and not in a cross-sectional study.

A strength of our study is the delimited age range of young children. During childhood, the lungs develop continuously, and age adaptations occur rapidly. Investigating a large sample of children of the same age; therefore, reduces a developmental impact and corresponding potential biases on our findings.

Given the association between WC and lung function, future studies should include the measurement of chest circumference and fat-free mass to ascertain the relationship between thoracic dimension, muscular strength, and lung function. Future studies should also evaluate the potential effect of sport-specific adaptation that has been already described in some physical activities, such as swimming (10), to elucidate a hypothetical variation in lung growth between exercise modalities which could be relevant in child development and also in pulmonary rehabilitation (11).

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References

1. Armour J, Donnelly PM, Bye PTP. The large lungs of elite swimmers: an increased alveolar number? *Eur Respir J*. 1993;6(2):237–47. doi: 10.1183/09031936.93.06020237
2. Barker DJP, Osmond C. Childhood respiratory infection and adult chronic bronchitis in England and Wales. *BMJ*. 1986;293(6557): 1271–75. doi:10.1136/bmj.293.6557.1271
3. Bekkers MBM, Wijga AH, de Jongste JC, et al. Waist circumference, BMI, and lung function in 8-year-old children: The PIAMA birth cohort study. *Pediatr Pulmonol*. 2013;48(7):674–82. doi:10.1002/ppul.22722
4. Berntsen S, Wisløff T, Nystad W, Nafstad P, Nystad W. Lung function increases with increasing level of physical activity in school children. *Pediatr Exerc Sci*. 2008;20(4):402–10. doi:10.1123/pes.20.4.402
5. Beydon N, Davis SD, Lombardi E, et al. An official American Thoracic Society/European Respiratory Society statement: pulmonary function testing in preschool children. *Am J Respir Crit Care Med*. 2007;175(12):1304–45. doi:10.1164/rccm.200605-642ST
6. Celis-Morales CA, Welsh P, Lyall DM, et al. Associations of grip strength with cardiovascular, respiratory, and cancer outcomes and all cause mortality: prospective cohort study of half a million UK Biobank participants. *BMJ*. 2018;361:k1651. doi:10.1136/bmj.k1651
7. Chen Y, Rennie D, Cormier Y, Dosman JA. Waist circumference associated with pulmonary function in children. *Pediatr Pulmonol*. 2009;44(3):216–21. doi:10.1002/ppul.20854
8. Cheng YJ, Macera CA, Addy CL, Sy FS, Wieland D, Blair SN. Effects of physical activity on exercise tests and respiratory function. *Br J Sports Med*. 2003;37(6):521–28. doi:10.1136/bjsm.37.6.521
9. Fredberg JJ, Inouye D, Miller B, et al. Airway smooth muscle, tidal stretches, and dynamically determined contractile states. *Am J Respir Crit Care Med*. 1997;156(6):1752–59. doi:10.1164/ajrccm.156.6.9611016
10. García I, Drobnic F, Arrillaga B, Pons V, Viscor G. Lung capacity and alveolar gas diffusion in aquatic athletes: implications for performance and health. *Apunts Sports Med*. 2021;56(209):339. doi:10.1016/j.apunsm.2020.100339
11. García I, Molina-Molina M, Arrillaga B, Javierre C, Viscor G. Swimming exercise for patients with long-term respiratory post COVID-19 complications: further thinking on the pulmonary rehabilitation. *Arch Bronconeumol*. 2022;58(6):527–28. doi:10.1016/j.arbres.2022.02.008
12. García-Hermoso A, Cavero-Redondo I, Ramírez-Vélez R, et al. Muscular strength as a predictor of all-cause mortality in an apparently healthy population: a systematic review and meta-analysis of data from approximately 2 million men and women. *Arch Phys Med Rehabil*. 2018;99(10):2100–13.e5. doi:10.1016/j.apmr.2018.01.008
13. Hancox RJ, Rasmussen F. Does physical fitness enhance lung function in children and young adults? *Eur Respir J*. 2018;51(2): 1701374. doi:10.1183/13993003.01374-2017
14. He QQ, Wong TW, Du L, et al. Respiratory health in overweight and obese Chinese children. *Pediatr Pulmonol*. 2009;44(10):997–1002. doi:10.1002/ppul.21091
15. Hsia CCW, Hyde DM, Weibel ER. Lung structure and the intrinsic challenges of gas exchange. *Compr Physiol*. 2016;6(2):827–95.
16. Iglesias-Soler E, Rúa-Alonso M, Rial-Vázquez J, et al. Percentiles and principal component analysis of physical fitness from a big sample of children and adolescents aged 6-18 years: The DAFIS project. *Front Psychol*. 2021;12:834. doi:10.3389/fpsyg.2021.627834
17. Jakes RW, Day NE, Patel B, et al. Physical inactivity is associated with lower forced expiratory volume in 1 second: European prospective investigation into cancer-norfolk prospective population study. *Am J Epidemiol*. 2002;156(2):139–47. doi:10.1093/aje/kwf021
18. Jurić P, Jurak G, Morrison SA, Starc G, Sorić M. Effectiveness of a population-scaled, school-based physical activity intervention for the prevention of childhood obesity. *Obesity*. 2023;31(3):811–22. doi:10.1002/oby.23695
19. Kanai M, Kanai O, Fujita K, Mio T, Ito M. Decreased handgrip strength can predict lung function impairment in male workers: a cross sectional study. *BMC Pulm Med*. 2020;20(1):1135. doi:10.1186/s12890-020-1135-9
20. Köchli S, Endes K, Bartenstein T, et al. Lung function, obesity and physical fitness in young children: The EXAMIN YOUTH study. *Respir Med*. 2019;159:105813. doi:10.1016/j.rmed.2019.105813
21. Latorre-Román PÁ, Navarro-Martínez AV, García-Pinillos F. The effectiveness of an indoor intermittent training program for improving

lung function, physical capacity, body composition and quality of life in children with asthma. *J Asthma*. 2014;51(5):544–51. doi:10.3109/02770903.2014.888573

22. Martin A, Saunders DH, Shenkin SD, Sproule J. Lifestyle intervention for improving school achievement in overweight or obese children and adolescents. *Cochrane Database Sys Rev*. 2014;3:CD009728. doi:10.1002/14651858.CD009728
23. Mazic S, Lazovic B, Djelic M, et al. Respiratory parameters in elite athletes - does sport have an influence? *Rev Port Pneumol*. 2015;21(4):192–7. doi:10.1016/j.rppnen.2014.12.003
24. McKenzie DC. Respiratory physiology: adaptations to high-level exercise. *Br J Sports Med*. 2012;46:381–4.
25. Mgbemena NC, Aweto HA, Tella BA, Emeto TI, Malau-Aduli BS. Prediction of lung function using handgrip strength in healthy young adults. *Physiol Rep*. 2019;7(1):e13960. doi:10.14814/phy2.13960
26. Pérez-Padilla R, Rojas R, Torres V, et al. Obesity among children residing in Mexico City and its impact on lung function: a comparison with Mexican-Americans. *Arch Med Res*. 2006;37(1):165–71. doi:10.1016/j.arcmed.2005.05.009
27. Quanjer PH, Stanojevic S, Cole TJ, et al. Multi-ethnic reference values for spirometry for the 3-95-yr age range: the global lung function 2012 equations. *Eur Respir J*. 2012;40(6):1324–43. doi:10.1183/09031936.00080312
28. Ripoll JG, Guo W, Andersen KJ, et al. Sex differences in paediatric airway anatomy. *Exp Physiol*. 2020;105(4):721–31. doi:10.1113/EP088370
29. Rosenthal M, Bain SH, Cramer D, et al. Lung function in white children aged 4 to 19 years: I-Spirometry. *Thorax*. 1993;48(8):794–802. doi:10.1136/thx.48.8.794
30. Rowe A, Hernandez P, Kuhle S, Kirkland S. The association between anthropometric measures and lung function in a population-based study of Canadian adults. *Respir Med*. 2017;131:199–204. doi:10.1016/j.rmed.2017.08.030
31. Schittny JC. Development of the lung. *Cell Tissue Res*. 2017;367(3):427–44. doi:10.1007/s00441-016-2545-0
32. Sheel AW, Richards JC, Foster GE, Guenette JA. Sex differences in respiratory exercise physiology. *Sports Med*. 2004;34(9):567–79. doi:10.2165/00007256-200434090-00002
33. Sillanpää E, Stenroth L, Bijlsma AY, et al. Associations between muscle strength, spirometric pulmonary function and mobility in healthy older adults. *Age*. 2014;36(4):9667. doi:10.1007/s11357-014-9667-7
34. Smith MP, Standl M, Berdel D, et al. Handgrip strength is associated with improved spirometry in adolescents. *PLoS One*. 2018;13(4):560. doi:10.1371/journal.pone.0194560
35. Steele RM, Finucane FM, Griffin SJ, Wareham NJ, Ekelund U. Obesity is associated with altered lung function independently of physical activity and fitness. *Obesity*. 2009;17(3):578–84. doi:10.1038/oby.2008.584
36. Taxová Braunerová R, Kunešová M, Heinen MM, et al. Waist circumference and waist-to-height ratio in 7-year-old children—WHO childhood obesity surveillance initiative. *Obes Rev*. 2021;22(Suppl 6):e13208. doi:10.1111/obr.13208

Queries

Q1. Please check edit maintains the intended meaning of the sentence "Our results corroborate the . . . ."

Q2. Keywords "children and lung function" were deleted, as repeats of article title words are not allowed in keywords section, per journal style. Provide additional keywords so that the total number of keywords equals at least 3, ideally 4–5.

Q3. Please ensure that author information at the time of the manuscript submission is listed correctly in the author byline. Any new affiliations after manuscript submission should be added as an author footnote.

Q4. Please provide ORCID for the authors "Juan Serrano-Ferrer and Anna Jodar-Portas" if they available.

Q5. Please provide significance of italics in Tables 1 and 2.

Q6. Please check the edits made in the Acknowledgments section.