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Better bone health in children and adolescents represents better performance in physical fitness

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Una mejor salud ósea en niños y adolescentes representa un mejor rendimiento en aptitud física

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ABSTRACT

Introduction: childhood and adolescence are the ideal time for the prevention of adequate bone health. Its evaluation in the school environment is important, since different levels of musculoskeletal health are related to bone mineral density.

Objective: to verify if there are differences in physical fitness in children and adolescents categorized as having low, adequate and high bone health.

Methodology: a cross-sectional study was developed in 704 males and 714 females (1418 schoolchildren) from a high-altitude region. Anthropometry was assessed: weight, height, physical tests [hand grip strength (HGS), horizontal jump (HJ), agility, and aerobic fitness (6MWT)]. Bone health from quantitative ultrasonography (QUS) of calcaneus [measured parameter was speed of sound (SOS, m/s)]. Body mass index (BMI) was calculated. Three bone health groups were formed: low, moderate and high altitude.

Results: at the primary level, no significant differences were found in the physical tests between the three bone health groups. Although, schoolchildren with high bone health (HBH) showed a slight performance. At the secondary level, and specifically in males, there were no significant differences in physical performance (HGS and 6MWT) between the categories low bone health (LBH) vs adequate bone health (ABH). However, in HJ and agility there were significant differences. In females, there were significant differences in the HJ and 6MWT test. The relationships observed between chronological age and broadband ultrasonic attenuation (BUA) in both sexes were positive and moderate ($r = 0.47$ in males and $r = 0.65$ in females). In addition, there were mild to moderate positive correlations in the HGS, HJ and 6MWT tests ($r = 0.22$ to 0.50, $p < 0.05$) and negative with the agility test ($r = -0.30$ to -0.39, $p < 0.05$).

Conclusion: the results show that good bone health is related to better physical performance. Having a high bone health status (LBH) is associated with better physical performance. While an adequate bone health status (ABH) does not always outperform high bone health (HBH). These results suggest promoting healthy habits to favor bone health from an early age.

Keywords: Bone health. Physical fitness. Schoolchildren. Broadband ultrasonic attenuation.

RESUMEN

Introducción: la infancia y la adolescencia son el momento idóneo para la prevención de una adecuada salud ósea. Su evaluación en el ámbito escolar es importante, ya que los diferentes niveles de salud musculoesquelética están relacionados con la densidad mineral ósea.

Objetivo: verificar si existen diferencias en la aptitud física en niños y adolescentes categorizados como de salud ósea baja, adecuada y alta.

Metodología: se desarrolló un estudio transversal en 704 varones y 714 mujeres (1418 escolares) de una región de altura. Se evaluó la antropometría: peso, altura, pruebas físicas [fuerza de agarre con las manos (HGS), salto horizontal (HJ), agilidad y aptitud aeróbica (6MWT)]. Se evaluó la salud ósea mediante ultrasonografía cuantitativa (QUS) del calcáneo [el parámetro medido fue la velocidad del sonido (SOS, m/s)]. Se calculó el índice de masa corporal (IMC). Se formaron tres grupos de salud ósea: baja, moderada y alta altitud.

Resultados: en el nivel primario, no se encontraron diferencias significativas en las pruebas físicas entre los tres grupos de salud ósea. Aunque, los escolares con salud ósea alta (HBH) mostraron un ligero rendimiento. En el nivel secundario, y específicamente en varones, no hubo diferencias significativas en el rendimiento físico (HGS y 6MWT)

entre las categorías salud ósea baja (HBH) vs salud ósea adecuada (HBA). Sin embargo, en HJ y agilidad sí hubo diferencias significativas. En las mujeres, hubo diferencias significativas en la prueba HJ y 6MWT. Las relaciones observadas entre la edad cronológica y la atenuación ultrasónica de banda ancha (BUA) en ambos sexos fueron positivas y moderadas (r = 0,47 en varones y r = 0,65 en mujeres). Además, se observaron correlaciones positivas de leves a moderadas en las pruebas de HGS, HJ y 6MWT (r = 0,22 a 0,50, p < 0,05) y negativas con la prueba de agilidad (r = -0,30 a -0,39, p < 0,05).
Conclusiones: los resultados muestran que una buena salud ósea está relacionada con un mejor rendimiento físico. Tener un alto estado de salud ósea (EH) se asocia con un mejor rendimiento físico. Mientras que un adecuado estado de salud ósea (ABH) no siempre supera a un alto estado de salud ósea (HBH). Estos resultados sugieren promover hábitos saludables para favorecer la salud ósea desde edades tempranas.

Palabras clave: Salud ósea. Forma física. Escolares. Atenuación ultrasónica de banda ancha.

INTRODUCTION

Assessing bone health is crucial throughout life, as it allows identifying early risk factors for fractures and diseases such as osteopenia and osteoporosis (1). Therefore, growth and development periods are considered to be the most conducive to increase bone mineral content, bone area and bone mineral density, due to high rates of bone modeling and remodeling, favored by increased mechanical loading (2).

During the first two decades of life, bone mass is mainly formed, and its accumulation continues until the third decade of life (3). In fact, childhood, especially adolescence, is the ideal time for the prevention of osteoporosis, since rapid skeletal growth occurs at this stage (4,5).

Therefore, the school environment is considered a favorable platform to assess and promote a physically active lifestyle. As there is an opportunity to reach all children and adolescents, especially those with low levels of physical fitness and impaired musculoskeletal health, including low bone mineral density (BMD) (6).

In that sense, physical fitness reflects the ability to perform daily tasks with vigor and alertness, without the presence of fatigue and with ample energy to enjoy leisure activities and to meet unforeseen emergencies (7). Thus, in recent years, several cross-sectional studies have been interested in investigating the relationships between physical fitness tests and bone health in children and adolescents. For example, upper extremity strength, lower extremity strength, agility tests, speed and cardiorespiratory fitness (CRF) have been shown to be strong predictors of bone health during the growth and development period (8-12).

Consequently, while current scientific evidence suggests that better bone health is related to greater physical fitness performance in children and adolescents, it remains unclear which specific components of physical fitness (muscular strength, speed, agility, cardiorespiratory fitness) have the greatest influence on bone health in children and adolescents. It has not yet been clearly determined which specific components of physical fitness (muscular strength, speed, agility, cardiorespiratory fitness) have a greater influence on bone health in children and adolescents.

To this end, the aim of this study was to verify whether there are differences in physical fitness in children and adolescents categorized as having low, adequate and high bone health. This information can be used to identify those children and adolescents with higher and/or lower risk of presenting low levels of physical fitness. This will allow the development of early intervention programs aimed at improving physical fitness and/or strengthening bone health during the school years.

MATERIAL AND METHODS

Type of study and sample

A cross-sectional study was developed in 704 males and 714 females (1418 schoolchildren) in a high-altitude region of Peru. The sample comes from a previous research project called physical fitness and health in schoolchildren. Data collection was carried out by convenience (non-probabilistic) in six public schools in the region. The region of Puno, located at 3,820 meters above sea level (13), is located in the southeast of the country (Peru) and is bordered to the east by the department of La Paz (Bolivia).

The study was conducted according to the Helsinki declaration for human subjects and in accordance with the suggestions described by the ethics committee of the University UNAP (CEIC 007-2022). Primary schoolchildren (6 to 11 years old) and secondary schoolchildren (12 to 17 years old) were included in the study. Schoolchildren who completed anthropometric measurements, bone health (calcaneal ultrasonography) and physical tests were included in the study. All parents and/or guardians of the schoolchildren authorized consent to participate voluntarily in the study.

Schoolchildren who were not within the established age range were excluded, as well as those with some type of physical and/or sports injury that prevented them from performing the physical tests and/or bone health assessment.

Techniques and procedures

The data collection process was carried out during the years 2022 and 2023. The principals of the six schools were informed of the purpose of the project. Once each principal authorized the participation of his or her school, consent forms were sent to the parents for their children to participate in the evaluations.

The team of evaluators consisted of four physical education professionals. The data collection process was carried out in two visits to each school. The first visit was to evaluate anthropometry and calcaneal ultrasonography. The second visit was to evaluate the physical tests.

Anthropometric variables

Weight and height were assessed with as little clothing as possible (barefoot, shorts and T-shirt) according to the suggestions described by Ross and Marfell-Jones (14). Body weight (kg) was measured using a Tanita digital scale (United Kingdom) with an accuracy of 0.1 kg and a range of 0.1 kg to 150 kg. Height was measured using a portable stadiometer (Hamburg, Seca Ltd.) with an accuracy of 0.1 mm and a measurement range of 0.0 cm to 220.0 cm. With both measurements (weight and height) the body mass index (BMI) was calculated. BMI = weight (kg) / height (m)^2].

Ultrasonography of the calcaneus

A SONOST 3000 bone densitometer (Seoul, South Korea), also known as QUS (quantum ultrasound) technology and characterized by being portable, inexpensive and free of ionizing radiation, was used. The equipment delivered three parameters: speed of sound (SOS, m/s); broadband ultrasonic attenuation (BUA, dB/MHz); and bone quality index (BQI = αSOS + βBUA, αβ: temperature corrections). For the study we used the BUA.

The assessment procedure consisted of schoolchildren sitting on a chair and with their right foot barefoot. Then, ultrasound gel was applied to improve the transmission of the waves and measurements were performed using the head of the equipment. The foot must remain inside the measuring chamber. The evaluation of each subject lasted approximately 15 to 20 seconds. To ensure reliability measures, the retest was applied. It was applied to 10 % of the sample studied (*n* =

142 schoolchildren of both sexes). The relative technical measurement error was 0.8 %.

Physical tests

Hand grip strength (HGS): the HGS of both hands (right and left) was evaluated. It was evaluated according to the suggestions described by Richards et al. (15). The evaluee sits on a straight-backed chair. Then one of the evaluators constantly adjusted the dynamometer to the grip size of the equipment according to age and sex. A JAMAR hydraulic dynamometer (Hydraulic Hand Dynamometer® Model PC-5030 J1, Fred Sammons, Inc., Burr Ridge, IL, USA) was used for the measurement. This equipment is accurate to 0.1 kg and has a scale of up to 100 kg/f.

Horizontal jump [HJ (m)]: the evaluated is placed behind a previously drawn line. It was evaluated according to the suggestions described by Castro-Piñero et al. (16). The person evaluated must perform preparatory movements of arms and knees to execute the jump. Once the jump is performed, the distance at the end of the heel is recorded. A metallic tape measure was used to record the distance from 0 to 3 m.

Agility 5 meters X 10 repetitions (seconds): it was evaluated using the suggestions described by Verschuren et al. (17). The evaluated should go in a back and forth direction, covering a distance of 5 meters until completing a total of 50 meters. At the end, 10 repetitions were performed. A Casio digital stopwatch with an accuracy of 0.01 seconds was used to measure the time.

Six-minute walk test (6MWT): this was performed following the recommendations of the American Thoracic Society (18). It was performed in an open space on a flat surface (30 meters long × 10 meters wide). This area was demarcated with white adhesive tape to distinguish the lanes. The evaluators instructed the schoolchildren to walk as fast as they could in one direction back and forth as fast as they could (without stopping). At the end of the 6 minutes, the distance achieved by each child was recorded.

The reliability of the physical tests was controlled through the test-retest technique. It was applied to 10 % of the sample (n = 142). The values of the relative technical measurement error ranged from 1.0 to 1.6 %.

Statistics

The normal distribution of the data was verified by means of the Kolmogorov-Smirnov test. The data were then analyzed descriptively, the mean, standard deviation were calculated. Significant differences between both sexes were determined by means of the t-test for independent samples. Comparison of physical fitness tests according to OS levels was determined via one-way ANOVA and Tukey's test of specificity. The categories of bone quality: low, moderate and high, were determined by means of the distribution of tertiles. With the first tercile being low bone quality (≤ 33rd percentile), the second tercile being moderate bone quality (> 33rd percentile and ≤ 66th percentile), and the third tercile as high bone quality (> 66th percentile). To examine the relationships between bone health and fitness tests, Pearson's correlation coefficients (r) were calculated. All statistical analyses were performed using SPSS v23.0 statistical software. Graphs were generated using the Python programming language. A probability of $p < 0.05$ was adopted in all cases.

RESULTS

The characteristics of the studied schoolchildren aligned in two levels (primary and secondary) are shown in table I. At the primary level, boys present higher weight, BMI, higher HJ and less time in the agility test than their female counterparts ($p < 0.05$). There were no differences in age, height, bone health, HGS (both hands) and 6-minute walk test (6MWT). At the secondary level, there were significant differences between both sexes in weight, height, BMI and the four physical tests (HGS, HJ, Agility and 6MWT). There were no significant differences in age and bone health ($p > 0.05$).

Table II presents the comparison of physical performance in three bone health groups: low bone health (BSO), adequate bone health (ABH) and high bone health (HBH). The data were grouped at the primary level (6 to 11 years) and secondary level (12 to 17 years).

After comparisons at the primary level between the three bone health groups, no significant differences were observed in the four physical tests (HGS, HJ, agility and 6MWT) ($p > 0.05$). Despite the fact that in the high bone health category (HBH) schoolchildren of both sexes showed slight superiority in relation to the other two categories.

At the secondary level, and specifically in males, there were no significant differences in physical performance (HGS and 6MWT) between the categories low bone health (LBH) vs adequate bone health (ABH) ($p > 0.05$). However, in the SH and agility tests there were significant differences ($p < 0.05$). It was also verified that there was a significant difference in the physical performance of the 4 physical tests (HGS, HJ, agility and 6MWT) when compared between LBH vs HBH ($p < 0.05$). In addition, when compared between ABH vs HBH, and ABH vs HBH there were significant differences in the 4 physical tests ($p > 0.05$).

In females, between the LBH vs ABH categories there were significant differences in the 4 physical tests (HGS, HJ, agility and 6MWT) ($p < 0.05$). When comparing the LBH vs HBH categories, there were significant differences in two physical tests (HGS and HJ) ($p < 0.05$); however, there were no differences in agility and agility and 6MWT ($p > 0.05$). On the other hand, in the comparisons between ABH vs HBH, there were no significant differences in the 4 physical tests ($p > 0.05$).

Figure 1 shows the relationships between chronological age with bone health values (BUA) and the latter with physical tests in both sexes. The relationships observed between chronological age with BUA in both sexes were positive and moderate (r = 0.47 in men and r = 0.65 in women). In addition, there were mild to moderate positive correlations in the HGS, HJ and 6MWT tests (r = 0.22 to 0.50, $p < 0.05$) and negative with the agility test (r = -0.30 to -0.39, $p < 0.05$).

DISCUSSION

The results of the study have shown that schoolchildren with high bone health (ESO) present better performance in tests of strength (HGSR and HGSL), agility, HJ and aerobic fitness (6MWT) compared to those with low bone health (LBH) and adequate bone health (ABH), especially at the secondary level. In addition, low to moderate relationships were observed between BUA values and the four physical tests (r = 0.22 to 0.50). This suggests an association between bone health and physical performance in schoolchildren.

In fact these findings are consistent with some studies performed in children and adolescents, reporting positive associations with bone health during childhood and adolescence and negative with agility (8-11). Although, in our study, we verified that during childhood (primary level 6 to 11 years), there were no significant differences in physical performance. But we did verify significant differences at the secondary level (12 to 17 years).

In fact, in childhood, differences in body size and maturation may be less pronounced compared to adolescence. Where hormonal changes and accelerated growth have a greater influence on strength, power and aerobic capacity (19). Furthermore, in elementary school children, bone and muscle growth is still at an early stage, so differences in bone density may not be marked enough to significantly influence physical performance.

In general, it is widely known that bone mass acquisition occurs slowly throughout childhood. Whereas it advances rapidly with the onset of puberty and at the time of the growth spurt. In that sense, peak bone mass occurred at 12.5 ± 0.90 years in girls and at 14.1 ± 0.95 years in boys (20). Therefore, this period represents a critical stage to optimize bone health through the practice of physical activity with impact, adequate diet rich in calcium and vitamin D, and a healthy lifestyle (21-23).

In fact, this may explain the differences found during adolescence (secondary level) in this study. For during this stage, bone mineral mass can be maximized, as it will have a significant impact on bone health later in adulthood and old age (23). Furthermore, muscle mass growth occurs during adolescence in both males and females, accompanying a linear increase in muscle strength (24). Since changes in body composition and muscle strength can be expected to directly influence bone mineral density.

In essence, puberty is the developmental period in which the transition from childhood to adult sexual maturity occurs. That is, the attainment of reproductive capacity and body and bone size (25). Thus, greater accumulation of bone mass in adolescence may contribute to greater bone strength and reduced risk of osteoporosis in adulthood (26).

In this context, increasing bone mineral density during adolescence may decrease the risk of fractures during old age (5), therefore, increasing peak bone mass in secondary schools through intervention programs may be critical. This developmental process results from the interaction of various genetic, environmental and behavioral factors (27,28). These strategies may reduce the risk factors associated with impaired bone health later in life, constituting an effective strategy for the prevention of osteoporosis (28).

The study presents some limitations that deserve to be described, for example, the sample selection was non-probabilistic and the design developed is cross-sectional. Therefore, the results of the study could not be generalized to other realities and/or sociocultural contexts. Furthermore, we are aware that, as this was a population-based study, it was not possible to collect information on food consumption and physical activity levels. Furthermore, we emphasize that future studies should consider the assessment of somatic maturation. Since this variable may significantly influence bone quality outcomes. In essence, controlling for these aspects may help to interpret and discuss with greater clarity and depth the results obtained in this study.

It also highlights some strengths, since it is one of the first studies carried out in Peru in an altitude region and can serve as a baseline for future comparisons in the same region and/or with other regions. In addition, this information can be used to implement activities during physical education classes to promote physical exercise, nutrition and a healthy lifestyle.

CONCLUSION

The results suggest that bone health has a significant relationship with physical performance, especially in secondary school children of both sexes. The results suggest that maintaining high bone health status (BHS) is associated with better physical performance compared to low bone health (LBH). However, having adequate bone health (ABH) does not necessarily imply better physical performance compared to high bone health (HBH).

REFERENCES

1. Pouresmaeili F, Kamalidehghan B, Kamarehei M, Goh YM. A comprehensive overview on osteoporosis and its risk factors. Ther Clin Risk Manag 2018;14:2029-49. DOI: 10.2147/TCRM.S138000

2. Specker B, Thiex NW, Sudhagoni RG. Does Exercise Influence Pediatric Bone? A Systematic Review. Clin Orthop Relat Res 2015;473(11):3658-72. DOI: 10.1007/s11999-015-4467-7
3. Cossio-Bolanos M, Vidal-Espinoza R, Fuentes-Lopez J, Castelli Correia de Campos LF, Andruske CL, Urra-Albornoz C, et al. Reference values for bone density and bone mineral content from 5 to 80 years old in a province of Chile. Peer J 2022;10:e13092. DOI: 10.7717/peerj.13092
4. Bonjour JP, Theintz G, Buchs B, Slosman D, Rizzoli R. Critical years and stages of puberty for spinal and femoral bone mass accumulation during adolescence. J Clin Endocrinol Metab 1991;73(3):555-63. DOI: 10.1210/jcem-73-3-555.
5. Rizzoli R, Bianchi ML, Garabédian M, McKay HA, Moreno LA. Maximizing bone mineral mass gain during growth for the prevention of fractures in the adolescents and the elderly. Bone 2010;46(2):294-305. DOI: 10.1016/j.bone.2009.10.005
6. Larsen MN, Nielsen CM, Helge EW, Madsen M, Manniche V, Hansen L, et al. Positive effects on bone mineralisation and muscular fitness after 10 months of intense school-based physical training for children aged 8-10 years: the FIT FIRST randomised controlled trial. Br J Sports Med 2018;52(4):254-60. DOI: 10.1136/bjsports-2016-096219
7. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 1985;100(2):126-31.
8. Gracia-Marco L, Vicente-Rodríguez G, Casajús JA, Molnar D, Castillo MJ, Moreno LA. Effect of fitness and physical activity on bone mass in adolescents: the HELENA Study. Eur J Appl Physiol 2011;111:2671-80.
9. Torres-Costoso A, Gracia-Marco L, Sánchez-López M, Notario-Pacheco B, Arias-Palencia N, Martínez-Vizcaíno V. Physical activity

and bone health in schoolchildren: the mediating role of fitness and body fat. PLoS One 2015;10(4):e0123797. DOI: 10.1371/journal.pone.0123797

10. Vlachopoulos D, Ubago-Guisado E, Barker AR, Metcalf BS, Fatouros IG, Avloniti A, et al. Determinants of Bone Outcomes in Adolescent Athletes at Baseline: The PRO-BONE Study. Med Sci Sports Exerc 2017;49(7):1389-96. DOI: 10.1249/MSS.0000000000001233
11. Cossio-Bolaños M, Lee-Andruske C, de Arruda M, Luarte-Rocha C, Almonacid-Fierro A, Gómez-Campos R. Hand grip strength and maximum peak expiratory flow: determinants of bone mineral density of adolescent students. BMC Pediatr 2018;18:96.
12. Gómez-Bruton A, Marín-Puyalto J, Muñiz-Pardos B, Lozano-Berges G, Cadenas-Sanchez C, Matute-Llorente A, et al. Association Between Physical Fitness and Bone Strength and Structure in 3- to 5-Year-Old Children. Sports Health 2020;12(5):431-40. DOI: 10.1177/1941738120913645
13. Sánchez-Macedo L, Vidal-Espinoza R, Minango-Negrete J, Ronque EV, Campos LFCC, Fuentes-López J, et al. Parameters of pubertal growth spurt in children and adolescents living at high altitude in Peru. J Pediatr (Rio J) 2024;100(2):189-95. DOI: 10.1016/j.jped.2023.08.010
14. Ross WD, Marfell-Jones MJ. Kinanthropometry. In MacDougall JD, Wenger HA, Geeny HJ (Eds.). Physiological testing of elite athlete; 1991. pp. 223, 308-314.
15. Richards LG, Olson B, Palmiter-Thomas P. How forearm position affects grip strength. Am J Occup Ther 1996;50(2):133-8. DOI: 10.5014/ajot.50.2.133
16. Castro-Piñero J, Ortega FB, Artero EG, Girela-Rejón MJ, Mora J, Sjöström M, et al. Assessing muscular strength in youth: usefulness of standing long jump as a general index of muscular fitness. J

Strength Cond Res 2010;24(7):1810-7. DOI: 10.1519/JSC.0b013e3181ddb03d
17. Verschuren O, Takken T, Ketelaar M, Gorter JW, Helders PJM. Reliability of running tests for measuring agility and anaerobic muscle power in children with cerebral palsy. Pediatr Phys Ther 2007;19:107-15. DOI: 10.1097/pep.0b013e318036bfce
18. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med 2002;166(1):111-7. DOI: 10.1164/ajrccm.166.1.at1102. Erratum in: Am J Respir Crit Care Med 2016;193(10):1185. DOI: 10.1164/rccm.19310erratum
19. Malina RM, Bouchard C, Bar-Or O. Growth, Maturation, and Physical Activity. 2nd ed. Champaign, IL: Human Kinetics; 2004.
20. Heaney RP, Abrams S, Dawson-Hughes B, Looker A, Marcus R, Matkovic V, et al. Peak bone mass. Osteoporos Int 2000;11(12):985-1009. DOI: 10.1007/s001980070020
21. Khan K, McKay HA, Haapasalo H, Bennell KL, Forwood MR, Kannus P, et al. Does childhood and adolescence provide a unique opportunity for exercise to strengthen the skeleton? J Sci Med Sport 2000;3(2):150-64. DOI: 10.1016/s1440-2440(00)80077-8
22. Proia P, Amato A, Drid P, Korovljev D, Vasto S, Baldassano S. The Impact of Diet and Physical Activity on Bone Health in Children and Adolescents. Front Endocrinol (Lausanne) 2021;12:704647. DOI: 10.3389/fendo.2021.704647
23. Weaver CM, Gordon CM, Janz KF, Kalkwarf HJ, Lappe JM, Lewis R, et al. The National Osteoporosis Foundation's position statement on peak bone mass development and lifestyle factors: a systematic review and implementation recommendations. Osteoporos Int 2016;27(4):1281-386. DOI: 10.1007/s00198-015-3440-3. Erratum in: Osteoporos Int 2016;27(4):1387. DOI: 10.1007/s00198-016-3551-5

24. Brown KA, Patel DR, Darmawan D. Participation in sports in relation to adolescent growth and development. Transl Pediatr 2017;6(3):150-9. DOI: 10.21037/tp.2017.04.03
25. Bonjour JP, Chevalley T. Pubertal timing, bone acquisition, and risk of fracture throughout life. Endocr Rev 2014;35(5):820-47. DOI: 10.1210/er.2014-1007
26. Han CS, Kim HK, Kim S. Effects of Adolescents' Lifestyle Habits and Body Composition on Bone Mineral Density. Int J Environ Res Public Health 2021;18(11):6170. DOI: 10.3390/ijerph18116170
27. Min SK, Oh T, Kim SH, Cho J, Chung HY, Park DH, et al. Position Statement: Exercise Guidelines to Increase Peak Bone Mass in Adolescents. J Bone Metab 2019;26(4):225-39. DOI: 10.11005/jbm.2019.26.4.225
28. Chevalley T, Rizzoli R. Acquisition of peak bone mass. Best Pract Res Clin Endocrinol Metab 2022;36(2):101616. DOI: 10.1016/j.beem.2022.101616

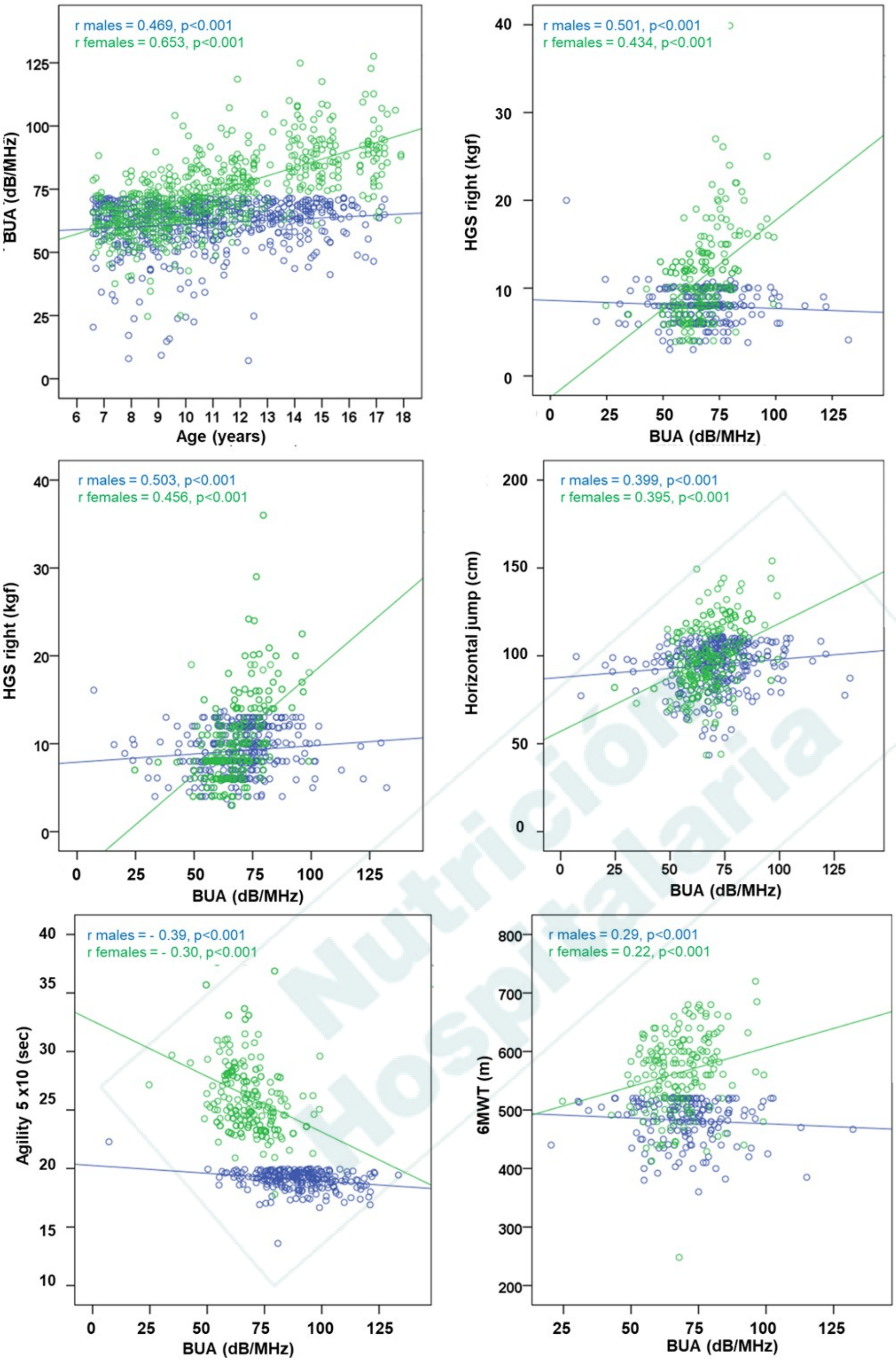

Figure 1. Relationship between age, bone health (BUA) and physical fitness tests in schoolchildren of both sexes.

Table I. Anthropometric, bone and physical profile of the schoolchildren studied

Variables	**Primary level**					**Secondary level**				
	Males (*n* = 443)		**Females (*n* = 165)**		**v-*p***	**Males (*n* = 664)**		**Females (*n* = 141)**		**v-*p***
	X	**SD**	**X**	**SD**		**X**	**SD**	**X**	**SD**	
Age (years)	9.4	1.6	9.2	1.5	0.163	14.7	1.5	14.6	1.8	0.488
Anthropometry										
Weight (kg)	33.9	9.8	31.9	9.6	0.024	55.6	11.8	52.4	10.3	0.0002
Height (cm)	133.1	10.1	131.8	10.8	0.166	162.1	8.6	152.8	6.1	0.0001
BMI (kg/m^2)	18.8	3.7	18	3.8	0.018	21.0	3.6	22.4	3.7	0.0001
Bone health										
BUA (dB/MHz)	69.7	15.5	67.4	12.2	0.086	84.1	16.4	86.4	12.5	0.116
Physical fitness										
HGSR (kg/f)	11	4.5	10.4	4.6	0.146	28.6	8.6	18.5	5.8	0.0001
HGSL (kg/f)	10.7	4.4	9.9	4.6	0.129	27.6	8.4	17.3	5.8	0.0001
HJ (cm)	105.5	24.1	96.5	20.7	0.001	148.9	25.9	117.8	21.5	0.0001
Agility (sec)	25.3	3.4	26.7	3.2	0.001	21.1	2.1	23.7	2.0	0.0001
6MWT (m)	556.8	71.0	562	67.3	0.415	638.9	60.3	581.5	63.2	0.0001

HGSR: hand grip strength right; HGSL: Hand grip strength left: BUA: broadband ultrasonic attenuation; BMI: body mass index; HJ: horizontal jump; 6MWT: 6-minute walk test.

Table II. Comparison of physical fitness according to bone health level in primary and secondary schoolchildren

Variables	Low bone health (LBH)		Adequate bone health (ABH)		High bone health (HBH)		Comparisons		
	X	SD	X	SD	X	SD	LBH-ABH	LBH-HBH	ABH-HBH
Primary level									
Males	(*n* = 38)		(*n* = 360)		(*n* = 45)				
HGSR (kg/f)	11.1	4.2	11.1	4.3	12.3	6.1	0.999	0.308	0.088
HGSL (kg/f)	10.8	4.7	10.7	4.1	12	6.4	0.888	0.341	0.063
HJ (cm)	103.5	16.6	107.1	24.1	108.3	29.1	0.369	0.318	0.758
Agility (sec)	25.7	3.2	25.3	3.3	24.3	3.2	0.476	0.050	0.055
6MWT (m)	551.5	61.8	556.3	69.3	569.5	75.2	0.6820	0.242	0.233
Females	(*n* = 15)		(*n* = 135)		(*n* = 15)				
HGSR (kg/f)	10.8	3.3	10.3	4.8	12.1	4	0.695	0.339	0.164
HGSL (kg/f)	10.1	3.4	9.6	4.8	12.2	4	0.695	0.132	0.045
HJ (cm)	96.1	16.5	96.3	19.4	107	24.2	0.969	0.160	0.050
Agility (sec)	26	2.3	26.6	3.1	26.3	3.7	0.468	0.791	0.727
6MWT (m)	556.9	59.3	561.3	65.6	580.7	81	0.804	0.366	0.290
Secondary level									
Males	(*n* = 58)		(*n* = 500)		(*n* = 106)				
HGSR (kg/f)	26.7	7.2	28	8.3	32.2	8.3	0.253	0.001	0.001
HGSL (kg/f)	25.1	7.3	26.9	8.1	30.8	7.5	0.106	0.001	0.001
HJ (cm)	138.7	25.7	147.7	25.1	155.8	25.7	0.010	0.001	0.008
Agility (sec)	21.9	2.1	21.3	2.2	20.6	2.1	0.048	0.001	0.008
6MWT (m)	623.6	64.6	635.9	60.4	653.1	60.2	0.145	0.003	0.009
Females	(*n* = 12)		(*n* = 117)		(*n* = 12)				
HGSR (kg/f)	14.5	5	19.1	7.1	21	5.7	0.044	0.019	0.371
HGSL (kg/f)	13.1	7	18	6.4	21.3	1.8	0.013	0.000	0.078
HJ (cm)	89.3	13.2	122.7	23.1	123.8	22.3	0.001	0.001	0.875
Agility (sec)	24.5	1.2	23.1	2.1	24.9	1.9	0.025	0.543	0.005

6MWT (m)	507	52.3	582.3	73.8	598.5	47.4	0.008	0.489	0.721

HGSR: hand grip strength right; HGSL: hand grip strength left; BUA: broadband ultrasonic attenuation; BMI: body mass index; HJ: horizontal jump; 6MWT: 6-minute walk test.