Physical fitness percentiles of Polish children aged 4–7 years

Karolina H. Przednowek1, Marta Niewczas1, Łukasz Wójcik2, Wojciech Paśko1, Janusz Iskra3 & Krzysztof Przednowek1

The purpose of this study was to report sex- and age-specific physical fitness level in Polish children aged 4 to 7. 11,709 children participated in the study, including 5,684 girls and 6,025 boys aged 4 to 7 who attended kindergarten institutions throughout Poland. Physical fitness was assessed using four tests developed by Sekita including shuttle run 4 × 5 m with moving the block, standing long jump, throwing 1 kg medicine ball with two hands above the head and 20 m run. Percentile charts were developed separately for males and females using the LMS method. Boys showed higher physical fitness values than girls. In addition, an increase in the level of physical fitness was observed along with the age of the subjects. The developed reference values by age and sex in the field of physical fitness can be used for diagnostic purposes and assessing the level of physical fitness of preschool children. In addition, they can be helpful for healthcare professionals, parents and teachers to develop children’s motor activation programs and monitor their physical fitness.

Physical fitness is a fundamental factor in proper development during childhood and adolescence1–3. It can, however, be assessed through various components, such as body composition, cardiopulmonary fitness, musculoskeletal fitness, motor fitness and flexibility. Currently, more than 15 tests are available around the world to assess the fitness level of children and adults. The most common of them are Eurofit, FitnessGram and Alpha-fit3. Cvejić assessed physical fitness with the Alpha-fit test, which included 4 trials: handgrip strength test, standing long jump, 20 m shuttle run test and 4 × 10 m shuttle run test2. Valentini used the Test of Gross Motor Development (TGMD-2) for motor assessment, which consisted of such components as run, hop, horizontal jump, leap or overhand throw4. Early assessment of preschool children is particularly important for monitoring the changes in their motor development, identifying developmental delays or deficiencies and for assistance in creating physical exercise programs8. Although the symptoms of many diseases appear in adulthood, the onset of the disease usually occurs in childhood7. Studies indicate that a higher level of physical fitness in childhood was associated with more positive health outcomes regarding the current and future risk of many diseases, such as obesity or cardiovascular diseases6,7. According to Ortega et al. high levels of cardiovascular fitness and muscular fitness improve the functioning of the cardiovascular system in young people6. Other report have shown that very low levels of muscle strength during puberty are associated with a higher risk of premature death from any cause before the age of 55, as well as due to cardiovascular disease6,9. Studies also show that preschool children (5 years old) with high levels of physical fitness were less obese and more concentrated. Such conclusions were reached by Lang et al. assessing cardiorespiratory fitness with the 20 m shuttle run test10. Qi et al. observed that after a 24-week training session, the group of studied children improved their motor skills (30-s speed tapping and throw a tennis ball) and hand grip strength, compared to the control group11. Leading an active lifestyle at this stage of life has also a positive effect on the child’s physical, cognitive and mental health6,12–14. Cantell et al. emphasize that a high level of physical fitness (ball catching and throwing, jump and clap, static and dynamic balance, foot and finger tapping at this age has a positive effect on the learning process and school achievements15. In addition, early years of life facilitate the acquisition of basic motor skills, which are associated with creating more complex and specialized movements16.

Analysis of the physical condition of Polish children in the years 1999–2009 showed a deterioration in the physical fitness of children and adolescents aged 6–1917. Studies by Wolanski and Dobosz have also demonstrated that negative tendencies in motor development also appear in younger children18. The recorded regress concerned 6 out of 9 motor tests and the largest was expressed in the flexibility, endurance and strength. Other reports have proven that, generally, the level of physical activity of children during the preschool period is systematically decreasing19. Many studies have shown that young children spend most of the day sitting and less than 5 percent

1Institute of Physical Culture Sciences, Medical College of Rzeszów University, Rzeszów University, 35-959 Rzeszów, Poland. 2Lower Silesian Regional Association of Traditional Karate, 50–529 Wroclaw, Poland. 3Faculty of Physical Education and Physiotherapy, Opole University of Technology, 45-758 Opole, Poland. *email: karprzed@ur.edu.pl
of the day on moderate-to-vigorous physical activities (MVPA). Data collected by the American Obesity Association (2004) and U.S. Department of Health and Human Services (2004) suggest that children are moving less and adopting a more sedentary lifestyle.

In the European countries studies have show the reference values for physical fitness of children and adolescents. However, due to the fact that the level of physical fitness is determined by biological and environmental factors, which are different in individual countries, it is impossible to compare the physical fitness of Polish children with the norms in other European countries. In Poland, percentile charts for physical fitness standards have been developed for children and adolescents aged 7–19. No studies have been conducted that would provide reference values for physical fitness in Polish children under 6 years of age (preschool). Therefore, the main purpose of this study was to provide reference percentile charts for the following parameters of physical fitness. The research used the Wroclaw Physical Fitness Test for preschool children developed by Sekita. The reason for choosing this method was its availability and simplicity in carrying out all the trials. This test covers the most important motor skills: strength (throwing a medicine ball weighing 1 kg), speed (20 m run), agility (shuttle run 4 × 5 m with moving the block) and power (standing long jump). Choosing a test to assess children's physical fitness, the authors also found that these tests were adapted to the level of motor abilities of preschool children.

### Material and methods

**Sample.** The research was carried out in 2016–2019 as part of the Ministerial project “Little Wonderful”. The project involved measuring the level of children's physical activity only. 11,709 children (5,684 girls and 6,025 boys) aged 4 to 7 participated. Decimal age was obtained from each child, and age groups were based on a complete year (i.e., 5.00 and 5.99 etc.). The most numerous group were children aged 5 (4,231 people) and 6 (4,359 people). The smallest group were 7-year-old children (1,194 people). More detailed data are included in Table 1. The children attended public preschool institutions throughout Poland. Sick, intellectually or physically disabled children were excluded from the study. Guardians of all the children expressed their willingness to participate in the project by giving a written consent. Before the study was initiated, the parents/legal guardians gave their informed consent to participate in the study of their children. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the University of Rzeszow/Poland (resolution 2/06/2010).

**Methods.** The assessment of the level of physical fitness of children was made using the Wroclaw Physical Fitness Test for preschool children developed by Sekita. The test for preschool children included: shuttle run 4 × 5 m with moving the block, standing long jump, throwing 1 kg medicine ball with two hands above the head and 20 m run.

Shuttle run 4 × 5 m with moving the block (agility) was adapted to the age of the children. This exercise is a modification of the agility test of the International Physical Fitness Test (IPFT). The modification concerned reducing the distance from 4 × 10 m to 4 × 5 m. The 5 m long surfaces were marked with two lines on which two blocks were placed at a distance of 20 cm. On the signal “run” the child covered the distance of 5 m four times moving the two blocks from the end line to the start line. Each child had two attempts. The time was measured with an accuracy of 0.1 s. The time for the best attempt, i.e. the fastest performed was taken into account.

During the standing long jump (power) the distance from the starting line to the heel or other part of the body that touched the floor closest to the starting line was measured. The child stood with their feet together in front of the starting line. They were ordered to make the longest leap forward. Each child had two attempts. The length was measured with an accuracy of 1 cm. The longest jump was taken into account.

Throwing 1 kg medicine ball with two hands above the head (strength) was measured in standing position. The beginning of the section was marked with a clearly seen line about 60 cm long. From this point the child made three throws. Then, every 10 cm lines were made on the floor parallel to the initial line indicating the

| Age/sex | N   | Agility (s) | Power (cm) | Strength (cm) | Speed (s) |
|---------|-----|-------------|------------|---------------|----------|
|        |     | x | sd | x | sd | x | sd | x | sd |
| 4 years | 1925 | 11.60 | 1.34 | 82.83 | 18.04 | 175.90 | 39.63 | 6.18 | 0.74 |
| Girls   | 927  | 11.71 | 1.34 | 80.64 | 18.14 | 169.36 | 37.76 | 6.27 | 0.77 |
| Boys    | 998  | 11.50 | 1.33 | 84.86 | 17.70 | 181.97 | 40.37 | 6.10 | 0.70 |
| 5 years | 4231 | 10.67 | 1.26 | 95.22 | 17.83 | 206.88 | 45.43 | 5.78 | 0.76 |
| Girls   | 2052 | 10.73 | 1.24 | 93.93 | 17.37 | 202.37 | 42.99 | 5.82 | 0.76 |
| Boys    | 2179 | 10.60 | 1.28 | 96.44 | 18.18 | 211.12 | 47.24 | 5.75 | 0.76 |
| 6 years | 4359 | 9.96  | 1.17 | 105.67 | 17.66 | 243.51 | 55.21 | 5.38 | 0.68 |
| Girls   | 2125 | 10.08 | 1.11 | 103.44 | 16.74 | 232.90 | 47.83 | 5.44 | 0.68 |
| Boys    | 2234 | 9.86  | 1.22 | 107.79 | 18.23 | 253.60 | 59.70 | 5.32 | 0.68 |
| 7 years | 1194 | 9.52  | 1.02 | 112.19 | 17.07 | 270.29 | 59.37 | 5.17 | 0.57 |
| Girls   | 580  | 9.67  | 1.01 | 108.86 | 16.68 | 257.84 | 52.95 | 5.22 | 0.57 |
| Boys    | 614  | 9.38  | 1.02 | 115.34 | 16.85 | 282.05 | 62.65 | 5.13 | 0.58 |
| Total   | 11709 | 10.44 | 1.38 | 98.80 | 19.91 | 221.89 | 57.79 | 5.64 | 0.78 |

Table 1. Results of individual physical fitness of Polish children aged 4–7 years.
same tests of physical fitness, smoothed LMS curves for the 3rd, 10th, 25th, 50th, 75th, 90th and 97th percentile abilities. Therefore, the percentiles should be interpreted in the opposite way, i.e. P3 is better than P10. For the cal fitness tests in a group of boys and girls aged 4 to 7. In the case of the tests where the result of the test was to performed better than girls in each physical fitness test except for the modified-back-saver-sit-and-reach tests. In their development even earlier. Children who score below P3 should be referred for further diagnosis in order diagnose physical fitness and refer to the norms for a given age. This would allow us to detect the irregularities (data from GUS—head statistics office in Poland). This means that at this stage of education you can already talents can be discovered27. Fitness reference standards have also been created for Spanish children aged 6–17. source of information for professionals—trainers, instructors or physical education teachers. On their basis sports statistical analysis. The LMS method was used in the study30. Parameters L, M, and S allow estimating the value of any centile for the age. In accordance with the WHO guidelines, while creating percentile charts the percentile values and LMS values were presented with an accuracy of 4 decimal numbers. This ensured appropriate smoothing of obtained centile curves by the age.

Results
Table 1 presents the results of individual motor tests taking into account the age and sex of the subjects. The analysis showed that boys present a higher level of tested abilities compared to girls. This phenomenon is observed in every age group and in the scope of all tested parameters—agility, power, strength and speed. At the same time, an increase in the level of analyzed motor skills is observed with the growing age of the girls and boys studied.

Table 2 presents smoothed percentiles (P3, P10, P25, P50, P75, P90 and P97) for sex and age in terms of physical fitness tests in a group of boys and girls aged 4 to 7. In the case of the tests where the result of the test was to obtain the shortest possible time (shuffle run 4 × 5 m and 20 m run), lower values indicate a higher level of these abilities. Therefore, the percentiles should be interpreted in the opposite way, i.e. P3 is better than P10. For the same tests of physical fitness, smoothed LMS curves for the 3rd, 10th, 25th, 50th, 75th, 90th and 97th percentile are shown in Fig. 1. Our data show a linear improvement in agility, power, strength and speed in both sexes.

Discussion
Currently, physical fitness is considered to be an important health indicator6,7. However, the diagnostic significance of physical fitness tests for children’s health is often neglected both at schools and at lower levels of education. It is known that the faster abnormalities in motor development of children are detected, the greater the chance of improving their health in adulthood. Many studies emphasize that children with motor disabilities are characterized by a low level of aerobic fitness31–33, which can lead to many diseases in adulthood. Considering that individual elements of physical fitness are associated with different health issues, these consequences constitute a concern for the current and later health condition of children with low motor competence34. Additionally, the term “developmental coordination disorder” (DCD) appears in the literature. It is a disorder in which the child has a problem, including the whole body movements and coordination, which causes problems with walking, running or jumping35. Research by Schott et al. suggests that children with DCD are prone to low levels of physical fitness compared to their peers31.

This work is the first attempt to provide physical fitness standards for preschool children based on research conducted for over 3 years (2016–2019). The study used 4 tests of physical fitness—agility, power, strength and speed. The analysis showed that the differences in the level of physical fitness between girls and boys are already visible in early childhood. This phenomenon is confirmed by many authors36–39.

Generally, there is an opinion that it is the school period that is the most appropriate stage to identify children with low levels of physical fitness and promote healthy behaviors6. In fact, a significant number of children attend kindergarten. For example, in Poland, in 2017/2018, over 1 million children attended this type of institution (data from GUS—head statistics office in Poland). This means that at this stage of education you can already diagnose physical fitness and refer to the norms for a given age. This would allow us to detect the irregularities in their development even earlier. Children who score below P3 should be referred for further diagnosis in order to determine other possible risk factors that may cause a disease38,40. Scientists from Germany came to similar conclusions37. They developed percentile fitness charts for children aged 9–12. According to them, this type of research is important not only for detecting developmental abnormalities. Percentile charts are an important source of information for professionals—trainers, instructors or physical education teachers. On their basis sports talents can be discovered37. Fitness reference standards have also been created for Spanish children aged 6–17. The percentile values presented concerned four aerobic fitness tests. The results of the Spanish population survey confirmed frequent sex differences in the studied parameters and it was noticed that boys perform better than girls41. A similar phenomenon was observed in this study—boys show a higher level of physical fitness compared to girls in each age group. This trend was also confirmed among the Portuguese children’s population26. Boys performed better than girls in each physical fitness test except for the modified-back-saver-sit-and-reach tests.
Other reports show that boys performed better than girls in such activities as catching, throwing and standing long jump42,43. Preschool children are in the phase of continuous motor, physiological and psychological changes44. We noticed that older children (both boys and girls) achieved better results in individual physical fitness tests compared to their younger colleagues. A similar phenomenon has been observed in many studies45,46. Comparing the results of Polish children with the results of the research conducted among the Portuguese population45 it is noted that the Polish population of boys and girls aged 6–7 presents a higher level of strength (standing long jump). For example, the P50 value in standing long jump in the group of Polish boys aged 6 is 106.96 cm. and in the Portuguese population 98.0 cm45. This tendency is also observed when comparing our results with the results from Macedonia47 and Southern Spain48. Correlating the presented parentel values in terms of power to the European data49 a higher level of strength (standing long jump) of Polish girls and preschool boys is also found. The P3 value for 6-year-old girls from the European population for the standing long jump is 56.6 cm, and P97—127.0 cm. However, for Polish girls the P3 value is 67.90 cm and P97—137.68 cm. Comparing the

| Age | Girls (N=5684) | Boys (N = 6025) |
|-----|----------------|-----------------|
|     | 3%  | 10%  | 25%  | 50%  | 75%  | 90%  | 97%  | 3%  | 10%  | 25%  | 50%  | 75%  | 90%  | 97%  |
| Agility (s) |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 4 years | 9.47 | 10.06 | 10.72 | 11.53 | 12.44 | 13.34 | 14.34 | 9.26 | 9.85 | 10.51 | 11.34 | 12.29 | 13.26 | 14.35 |
| 5 years | 8.75 | 9.30 | 9.91 | 10.66 | 11.49 | 12.33 | 13.25 | 8.55 | 9.10 | 9.71 | 10.48 | 11.36 | 12.25 | 13.26 |
| 6 years | 8.21 | 8.73 | 9.30 | 10.00 | 10.79 | 11.58 | 12.44 | 7.97 | 8.48 | 9.05 | 9.77 | 10.58 | 11.42 | 12.36 |
| 7 years | 7.83 | 8.32 | 8.87 | 9.54 | 10.29 | 11.04 | 11.86 | 7.54 | 8.02 | 8.56 | 9.24 | 10.01 | 10.80 | 11.69 |
| Power (cm) |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 4 years | 54.53 | 63.33 | 72.30 | 82.33 | 92.41 | 101.53 | 110.57 | 56.41 | 65.92 | 75.47 | 85.99 | 96.43 | 105.77 | 114.94 |
| 5 years | 62.02 | 72.03 | 82.24 | 93.65 | 105.12 | 115.49 | 125.77 | 63.57 | 74.28 | 85.05 | 96.90 | 108.67 | 119.19 | 129.53 |
| 6 years | 67.90 | 78.86 | 90.03 | 102.52 | 115.07 | 126.43 | 137.68 | 72.28 | 83.95 | 95.85 | 109.14 | 122.51 | 134.59 | 146.57 |
| 7 years | 72.28 | 83.95 | 95.85 | 109.14 | 122.51 | 134.59 | 146.57 | 161.40 | 190.53 | 221.52 | 257.60 | 295.31 | 330.57 | 366.57 |
| Strength (cm) |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 4 years | 105.76 | 124.86 | 145.17 | 168.81 | 193.52 | 216.63 | 240.22 | 110.85 | 148.57 | 172.74 | 200.87 | 230.27 | 257.78 | 285.85 |
| 5 years | 144.47 | 170.55 | 198.29 | 230.58 | 264.34 | 295.91 | 328.13 | 125.85 | 154.00 | 182.74 | 210.98 | 244.70 | 276.69 | 309.74 |
| 6 years | 161.40 | 190.53 | 221.52 | 257.60 | 295.31 | 330.57 | 366.57 | 150.47 | 179.68 | 211.28 | 248.70 | 288.44 | 326.15 | 365.11 |
| 7 years | 171.15 | 204.38 | 240.33 | 282.88 | 328.09 | 370.98 | 415.30 | 170.25 | 203.41 | 239.87 | 282.34 | 324.79 | 367.35 | 412.79 |
| Speed (s) |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 4 years | 5.05 | 5.35 | 5.70 | 6.15 | 6.68 | 7.25 | 7.91 | 4.92 | 5.22 | 5.57 | 6.02 | 6.54 | 7.10 | 7.74 |
| 5 years | 4.69 | 4.98 | 5.30 | 5.72 | 6.22 | 6.74 | 7.35 | 4.60 | 4.89 | 5.21 | 5.63 | 6.12 | 6.64 | 7.24 |
| 6 years | 4.41 | 4.68 | 4.98 | 5.38 | 5.84 | 6.33 | 6.91 | 4.31 | 4.58 | 4.89 | 5.28 | 5.74 | 6.22 | 6.78 |
| 7 years | 4.22 | 4.47 | 4.77 | 5.14 | 5.59 | 6.06 | 6.61 | 4.11 | 4.37 | 4.66 | 5.04 | 5.47 | 5.94 | 6.47 |

Table 2. Percentiles of physical fitness of Polish children aged 4–7 years.
**Figure 1.** Percentiles charts of physical fitness of Polish children aged 4–7 years.
results of own research with the research by Sanchez et al. a similar phenomenon is observed. The population of Polish preschool children shows a much higher level of lower-limb muscular strength (power) compared to the population of Spanish children. We observed that the P50 value in the studies by Sanchez et al. was definitely lower than in our research. This phenomenon was observed in all age groups for both sexes.

Given the differences in the methodology used, we are unable to compare our results with other studies. In most of the papers, the authors use the 4 × 10 m shuttle run test to assess agility. A shuttle run 4 × 10 m with moving the block was used in this study. Nevertheless, it was observed that P50 showed the same trend for boys and girls, improving with the age of the subjects, and the extent of the difference between the ages was systematic (0.4 to 0.8 s). Analyzing the speed test, we found only one paper in which the authors provide reference values using the 20 m run from high start test. P50 values for the speed test among the Lithuanian population of girls aged 6 and 7 were 5.96 s and 5.20 s, respectively, while for both sexes of the age group, 5.50 s and 5.02 s, respectively. Comparing the data of the Lithuanian population with the Polish population, it is noted that the results show comparable values, with a slight predominance of the Polish children. Nevertheless, better results in older children can be explained by the development of motor coordination in the preschool period. Improvements in speed scores were also shown among the European child population aged 6 to 9 years.

In terms of fitness, upper body muscle strength is considered to be a health condition predictor. One of the most popular tests to assess upper limb muscle strength is handgrip test. In this study, to assess the fitness of the upper limbs, it was decided to throw a medicine ball, which does not require special tools to evaluate this parameter. To our knowledge, this is the first study to provide a reference value for throwing a 1 kg medicine ball with two hands above the head in a large sample of preschool children. For example, Vaccari et al. also developed their own test to check the strength of the muscles of the upper limbs in the population of Italian children aged 6–11 years. The results of their research indicate an increase in the level of the tested ability with the age of the respondents (both in boys and girls). Additionally, it was observed that boys are characterized by lower efficiency of the upper limbs compared to boys. This phenomenon is also observed in these studies.

From a practical point of view, the developed reference standards of physical fitness allow us to classify preschool children in terms of the level of physical fitness: very poor (X < P10); poor (P10 ≤ X < P25); medium (P25 ≤ X < P75); good (P75 ≤ X < P90); and very good (X < P90). According to Miguel-Etayo et al., physical fitness below P5 may be a potentially pathological condition and a warning sign. Poor physical fitness outcomes may prompt the directly responsible persons, such as parents, doctors or school community, to solve the problem. Additionally, the authors conclude that children below P25 could be included in a physical activity program to improve their fitness, and children with higher percentile values (e.g. P90) could be directed towards further sports development.

Research limitations relate to the lack of basic anthropometric measurements (height and weight). Additionally, there are differences in biological age already at the preschool age. This means that more biologically mature children have a higher level of physical fitness. In some cases, the results may not be reliable, as the biological age can differ from the calendar age. The strength of the study is the large population of tested children aged 6–11 years. The results of their research indicate an increase in the level of the tested ability with the age of the respondents (both in boys and girls). Additionally, it was observed that boys are characterized by lower efficiency of the upper limbs compared to boys. This phenomenon is also observed in these studies.

The use of GAMLSS as a powerful tool to obtain smooth age-dependent reference curves is also a significant achievement. For example, the age of the study is the large population of tested children aged 4–7. The use of GAMLSS as a powerful tool to obtain smooth age-dependent reference curves is also a significant advantage of the study.

Conclusions
Based on the conducted research, percentile charts for four physical fitness tests of preschool children were developed. The presented parentel values can be helpful to classify and estimate the percentage of children with low or high levels of physical fitness. These findings will help health, sports, school and kindergarten workers. Our research shows that sexual dimorphism is already seen at the age of 4. In general, boys present a higher level of physical fitness than girls.

Received: 26 November 2020; Accepted: 19 March 2021
Published online: 01 April 2021

References
1. Timmons, B. W., Naylor, P.-J. & Pfeiffer, K. A. Physical activity for preschool children—how much and how? Appl. Physiol. Nutr. Metab. 32, 122–134 (2007).
2. Čvejić, D., Pejović, T. & Ostojić, S. Assessment of physical fitness in children and adolescents. Phys. Educ. Sport 11, 135–145 (2013).
3. Kolimechkov, S. Physical fitness assessment in children and adolescents: A systematic review. Eur. J. Phys. Educ. Sport Sci. (2017).
4. Valentini, N. C. Validity and reliability of the tgmd-2 for Brazilian children. J. Motor Behav. 44, 275–280 (2012).
5. McGill Jr, H. C., McMahan, C. A., of Atherosclerosis in Youth (PDAY) Research Group, P. D. et al. Determinants of atherosclerosis in Youth (PDAY) Research Group, P. D. et al. Determinants of atherosclerosis in the young. Am. J. Cardiol. 82, 30–36 (1998).
6. Ortega, F. B., Ruiz, J. R., Castillo, M. J. & Sjöstöm, M. Physical fitness in childhood and adolescence: A powerful marker of health. Int. J. Obes. 32, 1–11 (2005).
7. Ruiz, J. R. et al. Predictive validity of health-related fitness in youth: A systematic review. Br. J. Sports Med. 43, 909–923 (2009).
8. Ortega, F. B., Silventoinen, K., Tynelius, P. & Rasmussen, F. Muscular strength in male adolescents and premature death: Cohort study of one million participants. Bmj 345, e7279 (2012).
9. Metter, E. J., Talbot, L. A., Schrager, M. & Conwit, R. Skeletal muscle strength as a predictor of all-cause mortality in healthy men. J. Gerontol. A 57, B359–B363 (2002).
10. Lang, J. J. et al. Systematic review of the relationship between 20 m shuttle run performance and health indicators among children and youth. J. Sci. Med. Sport 21, 383–397 (2018).
11. Qi, Y., Tan, S., Sui, M. & Wang, J. Supervised physical training improves fine motor skills of 5-year-old children. Rev. Bras. Med. Esport. 24, 9–12 (2018).
12. Teixeira Costa, H. J., Abelairas-Gomez, C., Arufe-Giráldez, V., Pazos-Couto, J. M. & Barcala-Furelos, R. Influence of a physical education plan on psychomotor development profiles of preschool children. J. Hum. Sport Exerc. 10, 126–140 (2015).
13. 14. 21. 24. 32
13. Buck, S. M., Hillman, C. H. & Castelli, D. M. The relation of aerobic fitness to stroop task performance in preadolescent children. *Med. Sci. Sports Exerc.* 40, 166–172 (2008).
14. Becker, D. R., McClelland, M. M., Loprinzi, P. & Trost, S. G. Physical activity, self-regulation, and early academic achievement in preschool children. *Early Educ. Dev.* 25, 56–70 (2014).
15. Cantell, M. H., Smyth, M. M. & Ahonen, T. P. Clumsiness in adolescence: Educational, motor, and social outcomes of motor delay detected at 5 years. *A Adapt. Phys. Act. Q.* 11, 115–129 (1994).
16. Fang, H. et al. Relationship between physical activity and physical fitness in preschool children: A cross-sectional study. *BioMed Res. Int.* 2017, 1–8 (2017).
17. Woynarowska, B. & Oblacinska, A. Stan zdrowia dzieci i młodziezy w Polsce. Najwazniejsze problemy zdrowotne. *Stud. BAS* 2, 41–64 (2014).
18. Wolanśki, N. Dobosz j.: Tendencje przemian motoryczności człowieka (międzydekadowe zmiany efektywności). Uwarunkowanie rozwoju dzieci i młodzieży wiejskiej, *Biela Podlaska* 8–44 (2012).
19. Merkiel, S., Chalcarz, W. & Deptula, M. Porównanie aktywności fizycznej oraz ulubionych form spędzania czasu wolnego dziewczyn i chłopców w wieku przedszkolnym z województwa mazowieckiego. *Roczniki Państwowego Zakładu Higierny* 62, (2011).
20. Finn, K., Johannsen, N. & Specker, B. Factors associated with physical activity in preschool children. *J. Pediatr.* 140, 81–85 (2002).
21. Montgomery, C. et al. Relation between physical activity and energy expenditure in a representative sample of young children. *Am. J. Clin. Nutr.* 80, 591–596 (2004).
22. Reilly, J. J. et al. Total energy expenditure and physical activity in young scottish children: Mixed longitudinal study. *Lancet* 363, 211–212 (2004).
23. Stodden, D. F. et al. A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest* 60, 290–306 (2008).
24. Castro-Piñero, J., et al. Percentile values for muscular strength field tests in children aged 6 to 17 years: Influence of weight status. *J. Strength Condit. Res.* 23, 2295–2310 (2009).
25. De Miguel-Itayo, P. et al. Physical fitness reference standards in european children: The idefics study. *Int. J. Obes.* 38, S57–S66 (2014).
26. Santos, R. et al. Physical fitness percentiles for portuguese children and adolescents aged 10–18 years. *J. Sports Sci.* 32, 1510–1518 (2014).
27. Golle, K., Muehlbauer, T., Wick, D. & Granacher, U. Physical fitness percentiles of german children aged 9–12 years: Findings from a longitudinal study. *Plos ONE* 10, (2015).
28. Dobosz, J., Mayorga-Vega, D. & Viciana, J. Percentile values of physical fitness levels among polish children aged 7 to 19 years—a population-based study. *Central Eur. J. Public Health* 23, 340–351 (2015).
29. Osiński, W. *Antropomotoryka* (Academy of Physical Education in Poznan, 2003).
30. Yee, T. W. Effect of weight status. *Nutr. Hosp.* 28, 438–450 (2007).
31. Schott, N., Alof, V., Hultsch, D. & Meermann, D. Physical fitness in children with developmental coordination disorder. *Res. Q. Exerc. Sport* 78, 1245–1252 (2013).
32. Tanaka, C., Hikihara, Y., Ohkawara, K. & Tanaka, S. Locomotive and non-locomotive activity as determined by triaxial accelerometers and physical fitness in Japanese preschool children. *Pediatr. Exerc. Sci.* 25, 625–635 (2013).
33. Cadenas-Sanchez, C. Percentile values for muscular strength field tests in children aged 6 to 17 years: Influence of weight status. *J. Sci. Med. Sport* 16, 436–440 (2013).
34. Cadenas-Sanchez, C. Assessing physical fitness in preschool children: Feasibility, reliability and practical recommendations for the prefit battery. *J. Sci. Med. Sport* 19, 910–915 (2016).
35. Latorre-Román, P. A., García-Pinillos, F. & Mora-López, D. Reference values of standing long jump in preschool children: A population-based study. *Pediatr. Exerc. Sci.* 29, 116–120 (2017).
36. Kolimechkov, S., Petrov, L. & Alexandrova, A. Alpha-fit test battery norms for children and adolescents from 5 to 18 years of age (Academy of Physical Education in Poznan, 2003).
Competing interests
The authors declare no competing interests.

Additional information
Correspondence and requests for materials should be addressed to K.H.P.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

© The Author(s) 2021