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Original article

Using physical examinations to estimate age in elementary school children: A Chinese population-based study

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Abstract

Background: Designing a simple and accessible approach to age estimation in children and youth is a great challenge in the fields of sports and physical activity (PA). This study was designed to develop and validate a physical-examination-based method of estimating age in young children.
Methods: In a cross-sectional study conducted in 2014, we performed physical examinations and assessed PA among 14,970 elementary school children 7–12 years old in Shanghai, China. Additional biological information on the children's height and birth date was ascertained through their parents. Two indicators were applied to develop a gender-specific age estimation equation: The percentage of predicted mature height (PPMH) and the Tanner stage. The equation was validated through a *k*-fold cross-validation approach. To check for estimation accuracy, the association between the discrepancy of estimated age (EA) and chronological age and PA was examined.
Results: The gender-specific equations of EA were as follows: $EA_{boy} = –6.071 + 6.559$ Tanner 2 + 13.315 Tanner 3 + 14.130 Tanner 4 + 0.190 PPMH – 0.071 Tanner 2 × PPMH – 0.146 Tanner 3 × PPMH – 0.155 Tanner 4 × PPMH; $EA_{girl} = –4.524 – 1.251$ Tanner 2 + 2.504 Tanner 3 + 8.752 Tanner 4 + 11.893 Tanner 5 + 0.158 PPMH + 0.017 Tanner 2 × PPMH – 0.024 Tanner 3 × PPMH – 0.087 Tanner 4 × PPMH – 0.118 Tanner 5 × PPMH. The mean absolute error was 0.60 years for boys and 0.59 years for girls. The discrepancy score was negatively and weakly associated with self-reported moderate-to-vigorous PA in both genders ($r_{boy} = –0.09$, $p < 0.001$; $r_{girl} = –0.12$, $p < 0.001$).
Conclusion: Findings suggest that physical examinations could provide a valid and reliable approach for estimating age in young Chinese children.

Keywords: Age estimation; Growth and maturation; Physical activity; Physical examination; Skeletal age; Sports

1. Introduction

It is well known that growth and maturation vary considerably among children of the same chronological age (CA). Therefore, it is important that an accurate estimate of age across various developmental stages is available for use in studies of growth and performance in children and youth populations. In the realm of physical activity (PA), age information is often applied in reference to age verification in sports,[1] maturity-related variation in performance and levels of PA,[2,3] assessing injury risk,[4] searching for talented youth athletes,[5] and seeding (or matching) participants in youth sport competitions.[3,6] Thus, it is imperative that technically practical, accurate, and scientifically valid methods of estimating age in children be developed.

There are various methods available for age estimation,[5,7] including skeletal maturity, dental age, teeth development, and physical examination. The estimation involves somatic growth (e.g., body height and weight) and sexual maturity. A combined approach that uses both anthropometric measures and skeletal age to derive an estimation for maturity has also proven to be useful.[8,9] Although skeletal and dental maturity are the most commonly used objective methods, they are expensive and inevitably involve exposure to ionizing radiation, which may be harmful to health. In comparison, physical examination is a noninvasive, inexpensive, and potentially widely accessible assessment approach, and applicable to sports and PA.[10,11]

In the current study, we combined multiple biological maturity indicators to build an age estimation regression model. Consequently, our primary objective was to develop an age

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estimation equation for Chinese elementary school boys and girls using physical examination indicators. Because of the importance of considering PA when estimating age,[2,12] we also examined the association between levels of PA and CA, estimated age (EA), and discrepancy between CA and EA among Chinese children.

2. Methods

2.1. Study design and population

For this study, we used a cross-sectional, multistage sampling design, which involved a large-scale elementary school survey conducted in Shanghai, China, in 2014. Using a multistage sampling scheme, in Stage 1 we selected 7 of the 17 districts in the Shanghai metropolitan area. The districts were stratified based on the socioeconomic characteristics of urban and rural communities. In Stage 2, twenty-six elementary schools within the sampled districts were randomly sampled without stratification, with a varying number of schools within each of these districts: Jing'an (1 school), Changning (2 schools), Zhabei (2 schools), Jiading (2 schools), Jinshan (3 schools), Pudong (13 schools), and Chongming (3 schools). In Stage 3, classes within the sampled schools were randomly selected.

The target population consisted of elementary school children who were (1) between 7 and 12 years old, (2) able to complete survey questionnaires and anthropometry assessments, and (3) with a height z-score between −3.0 and +3.0. During recruitment, all children in schools that had less than 1000 students were invited to participate whereas in schools that had more than 1000 students only half of the classes in each grade were invited to participate. The study protocol was approved by the Shanghai Children's Medical Center Human Ethics Committee (SCMCIRB-K2014033), and parents of each participating child provided written informed consent.

2.2. Procedures

Upon completion of the sampling of the districts, schools, and classes, an invitation letter was sent to 17,620 children within the sampled schools and classes. Trained research assistants recruited the participants per study eligibility criteria. After parents consented to have their child participate in the study, assessments were conducted by trained research assistants or physicians in a private room. Assessments were conducted and completed in 2014.

2.3. Measures of sociodemographic characteristics and CA

Parents of the children were asked to complete a questionnaire that included information about the child's birth date, gender, weight, and height. To reduce the likelihood of overestimating, self-reported parental heights were adjusted according to the following formulas: height = 2.803 + 0.953 × (reported height) for women and 2.316 + 0.955 × (reported height) for men.[13] The CA for each participant was calculated by subtracting the date of birth given on the survey from the date of the physical examination. This age was recorded in years and months and was then converted to years by rounding it to the nearest 2 decimal places.

2.4. Children's physical examination

Following a standardized protocol, each child's height (cm) was recorded in duplicate using a calibrated Harpenden stadiometer (Holtain Ltd., Crosswell, UK). During the assessment, the child was instructed to stand straight on the scale with his or her shoes removed and head positioned against the meter. Measurements were taken in the morning by 2 different physicians and were recorded to the nearest 0.05 cm. The average of 2 values was taken as the child's height.

Tanner stage for each child was assessed, in a private room, by physicians. The stage of breast development for girls was rated by visual inspection[14] and the testicular volume for boys was estimated by comparative palpation with the Prader orchidometer (Takeda (China) Holdings Co., Ltd., Shanghai, China).[15] The assessment of breast development included 5 stages representing a progression from immaturity to full maturity. Testicular volume was graded into 4 stages: Stage 1 (<4 mL, prepubertal stage), Stage 2 (≥4 to <12 mL, early pubertal stage), Stage 3 (≥12 to <20 mL, mid-pubertal stage), and Stage 4 (≥20 mL, fully matured stage).[16] We decided to use breast development levels for girls and testicular volume stage for boys as pubertal maturation indicators because they are the first stages of puberty followed by pubic hair development in the vast majority of children. Both measures have shown a stronger correlation with height growth than with pubic hair appearance.[14,17] A final rating of Tanner stage was reached by consensus between the 2 physician examiners.

Serving as a major indicator of biological maturity, the percentage of predicted mature height (PPMH) was calculated as the current height of a child divided by his or her predicted mature height, which was calculated by the height for Parental Height formula as follows: 45.99 + 0.78 × (midparent height) for boys and 37.85 + 0.75 × (midparent height) for girls. The Parental Height formula has been shown to be a better predictor of mature height in Asian children than other formulas (e.g., the Corrected Midparental Height).[18] The midparent height was taken as the average of maternal and paternal current heights.

2.5. Self-reported PA

PA for each child was measured by the Chinese version of the Children's Leisure Activities Study Survey (C-CLASS), which has been validated with the objectively measured accelerometer data.[19] The C-CLASS includes leisure-time activities, school physical education classes, and transportation-related activities performed during the previous week. Children's PA data were categorized into vigorous PA (VPA), moderate-to-vigorous PA (MVPA), moderate PA (MPA), and light PA (LPA), as reported for weekdays and weekends.

2.6. Data analysis

It was likely that the multistage sampling may have resulted in clustered data (i.e., children were nested with classes, which nested within schools, which nested within districts). Therefore, we first examined the intraclass correlation in the data. Because of the small magnitude in intraclass correlation (0.009) and the lack of sampling weights in the data, we conducted the analyses