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

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Received 14 December 2016; revised 7 February 2017; accepted 24 February 2017
Available online 16 March 2017

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: 

- For boys: 
  \[ EA_{\text{boy}} = -0.071 \times \text{PPMH} + 1.189 \times \text{Tanner 2} + 2.504 \times \text{Tanner 3} + 8.752 \times \text{Tanner 4} - 0.146 \times \text{PPMH} - 0.155 \times \text{Tanner 3} + 14.130 \times \text{Tanner 4} + 0.190 \]

- For girls: 
  \[ EA_{\text{girl}} = -0.12 \times \text{PPMH} + 0.017 \times \text{Tanner 2} + 0.001 \times \text{Tanner 3} + 0.017 \times \text{Tanner 4} - 0.158 \times \text{PPMH} - 0.087 \times \text{Tanner 3} + 0.024 \times \text{Tanner 4} - 0.118 \times \text{Tanner 5} + 0.158 \times \text{PPMH} + 0.017 \times \text{Tanner 3} + 0.024 \times \text{Tanner 4} - 0.118 \times \text{Tanner 5} \]

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_{\text{ppm}} = -0.09, p < 0.001; r_{\text{pph}} = -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. © 2017 Production and hosting by Elsevier B.V. on behalf of Shanghai University of Sport. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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, | maturity-related variation in performance and levels of PA, | assessing injury risk, | searching for talented youth athletes, | and seeding (or matching) participants in youth sport competitions. |

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, 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. 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.

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...
estimation equation for Chinese elementary school boys and girls using physical examination indicators. Because of the importance of considering PA when estimating age, 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 \times (reported height) for women and 2.316 + 0.955 \times (reported height) for men. 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 and the testicular volume for boys was estimated by comparative palpation with the Prader orchidometer (Takeda (China) Holdings Co., Ltd., Shanghai, China). 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). 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. 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 her predicted mature height, which was calculated by the height for Parental Height formula as follows: 45.99 + 0.78 \times (midparent height) for boys and 37.85 + 0.75 \times (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). 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. 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
without accounting for clustering. To address whether CA, Tanner stage, and PPMH were related, zero-order Pearson correlations were computed for each gender. A gender-specific equation for age estimation was formulated and tested using a generalized linear model in which CA was the dependent variable and Tanner stages and PPMH were independent predictors. Because there was a significant interaction between Tanner stage and PPMH in relation to CA, we included the interaction term in the linear models. Tanner Stage 1 was used as the reference group in each model tested.

We used the k-fold cross-validation procedure to evaluate prediction error in the age estimation equation. Specifically, the total sample was divided into k = 5 subsets of equal size, stratified by Tanner stage, to ensure that the proportion of each Tanner stage was equally distributed in the subsets. Four of the 5 (k – 1) subsets were used as a training set, and the remaining subset was used as a test set to validate the model. This process was repeated 5 times, with each child in the dataset involved in the training set exactly 4 times and the test set once. The fitness of models across all trials was measured by mean absolute error (MAE) and root of mean standard error (RMSE), with smaller MAE or RMSE values indicating a better fit of the model under scrutiny. Pearson correlations were also computed to examine the relationship between various levels of PA and (1) EA and (2) the discrepancy between EA and CA, across gender.

To ensure accuracy, data on self-reported surveys and anthropometric measurements were double entered in EpiData 3.1 (EpiData as freeware from http://www.epidata.dk), and they were checked for outliers and verified by 2 research assistants. Statistical analyses were performed using SPSS Version 20.0 for Windows (IBM Corp., Armonk, NY, USA). The tests were considered statistically significant at a 2-sided p value < 0.05.

3. Results

3.1. Study population characteristics

All 26 of the schools invited to participate in the survey study agreed to participate. Of the 17,620 mailed invitations sent to the children and their families within the study sampling area, 16,958 agreed to participate, with a high response rate of 96%. After initial screening, 14,970 children (9.3 ± 1.4 years, mean ± SD; range: 7–12 years) (boys = 7997; girls = 6973) met the study inclusion criteria and were included in the final analysis.

As can be seen in Table 1, a significant number of the children’s parents reported their own paternal (35.62%) and maternal (36.85%) education at an “undergraduate” level. With respect to the level of PA, 7061 (88.3%) of the boys and 6340 (90.9%) of the girls reported an average of 0.44 h/day in VPA, 6089 (76.1%) of the boys and 5305 (76.1%) of the girls reported an average of 1.26 h/day in MPA, 5754 (72.0%) of the boys and 5078 (72.8%) of the girls reported an average of 1.68 h/day in MVPA, and 6754 (84.5%) of the boys and 6072 (87.1%) of the girls reported an average of 3.70 h/day in LPA.

| CA (year) | Boys (n = 7997) | Girls (n = 6973) | Total (n = 14,970) |
|-----------|----------------|-----------------|-------------------|
| ≥7 and <8 | 1872 (23.41)   | 1572 (22.54)    | 3444 (23.01)      |
| ≥8 and <9 | 1786 (22.33)   | 1501 (21.53)    | 3287 (21.96)      |
| ≥9 and <10| 1736 (21.71)   | 1600 (22.94)    | 3336 (22.28)      |
| ≥10 and <11| 1464 (18.31)  | 1294 (18.56)    | 2758 (18.42)      |
| ≥11       | 1139 (14.24)   | 1006 (14.43)    | 2145 (14.33)      |
| Height (cm)| 137.52 ± 9.82 | 137.16 ± 10.54 | 137.35 ± 10.16    |
| Body (kg) | 34.50 ± 10.29  | 30.20 ± 9.10    | 33.43 ± 9.82      |
| BMI (kg/m²)| 17.92 ± 3.47  | 16.83 ± 2.89    | 17.41 ± 3.26      |
| PA (h/day) |              |                 |                   |
| VPA        | 0.48 ± 0.58    | 0.39 ± 0.52     | 0.44 ± 0.56       |
| MPA        | 1.19 ± 0.93    | 1.34 ± 0.98     | 1.26 ± 0.96       |
| MVPA       | 1.65 ± 1.26    | 1.70 ± 1.22     | 1.68 ± 1.24       |
| LPA        | 3.66 ± 2.73    | 3.74 ± 2.67     | 3.70 ± 2.70       |
| Paternal education | | | |
| Junior high school and below 2363 (30.22) | 1836 (26.86) | 4199 (28.65) |
| Senior high school | 2378 (30.41)  | 2132 (31.19)    | 4510 (30.78)      |
| Undergraduate | 2688 (34.38)  | 2532 (37.04)    | 5220 (35.62)      |
| Postgraduate | 390 (4.99)    | 336 (4.91)      | 726 (4.95)        |
| Maternal education | | | |
| Junior high school and below 2679 (34.53) | 2203 (32.44) | 4882 (33.56) |
| Senior high school | 2093 (26.98)  | 1836 (27.04)    | 3929 (27.01)      |
| Undergraduate | 2780 (35.83)  | 2582 (38.02)    | 5362 (36.85)      |
| Postgraduate | 206 (2.66)    | 170 (2.50)      | 376 (2.58)        |

Note: Questionnaire returned with missing information for the paternal and maternal education.

* n (%).

b mean ± SD.

Abbreviations: BMI = body mass index; CA = chronological age; LPA = light PA; MPA = moderate PA; MVPA = moderate-to-vigorous PA; PA = physical activity; VPA = vigorous PA.
With respect to Tanner stage, a vast majority of the boys (74.5%) were classified in Stage 1, followed by Stage 2 (23.0%), and Stages 3 and 4 combined (2.5%). Among girls, more than one-third were classified in either Stage 1 (39.5%) or Stage 2 (31.4%), followed by Stages 3 (18.1%), and 4 and 5 combined (11.0%) (Table 2).

3.2. Associations between CA and Tanner stage, and PPMH

Results of the correlational analyses showed a positive relationship between CA and Tanner stage and PPMH, indicating that as age increased, the children’s Tanner stage became more advanced (i.e., more mature) \( r_{\text{boy}} = 0.60, p < 0.001; r_{\text{girl}} = 0.66, p < 0.001 \). Likewise, biological maturity was indicated by PPMH \( r_{\text{boy}} = 0.81, p < 0.001; r_{\text{girl}} = 0.83, p < 0.001 \). There was also a moderate-to-high association between PPMH and Tanner stage \( r_{\text{boy}} = 0.57, p < 0.001; r_{\text{girl}} = 0.73, p < 0.001 \).

3.3. EA equations

Results from the linear regression models of CA are shown in Table 3. The regression analysis using Tanner stage and PPMH data resulted in the following equation to predict the EA for boys and girls:

\[
\text{EA}_{\text{boy}} = -6.071 + 6.559 \times \text{Tanner} \begin{cases} 
2 
+ 13.315 \times \text{PPMH} \\
3 + 14.130 \times \text{Tanner} + 0.190 \times \text{PPMH} \\
4 - 0.071 \times \text{Tanner} \\
5 - 0.158 \times \text{Tanner} 
\end{cases}
\]

\[
\text{EA}_{\text{girl}} = -4.524 - 1.251 \times \text{Tanner} \begin{cases} 
2 + 8.752 \times \text{PPMH} \\
3 + 11.893 \times \text{Tanner} + 0.158 \times \text{PPMH} \\
4 + 0.017 \times \text{Tanner} \\
5 - 0.087 \times \text{Tanner} 
\end{cases}
\]

The above equations show that, for boys (Eq. (1)), the mean EA calculated was 9.23 years (95% confidence interval (CI): 9.21–9.26); for girls (Eq. (2)), the mean EA calculated was 9.26 years (95% CI: 9.24–9.29). The MAE value was 0.60 years for boys and 0.59 years for girls, respectively. The RMSE of CA was 0.75 years for boys and 0.74 years for girls, respectively (Tables 4 and 5).

3.4. Cross-validation

Results from 5-fold cross-validation are shown in Table 4 (boys) and Table 5 (girls). When evaluated by 1 sample t test, we found that iteration coefficients yielded from k-fold
### Table 4
Generalized linear model of CA and 5-fold cross-validation among boys (β (95%CI)).

|                | Total sample | Model 1 (n = 1572) | Model 2 (n = 1571) | Model 3 (n = 1623) | Model 4 (n = 1647) | Model 5 (n = 1584) |
|----------------|--------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| **Intercept**  | -6.071       | -6.198              | -6.030              | -6.009              | -6.072              | -6.046              |
| **95%CI**      | (-6.400 to 9.742) | (-6.636 to -5.833) | (-6.400 to -5.661) | (-6.379 to -5.639) | (-6.444 to -5.699) | (-6.409 to -5.683) |
| **Tanner 1**   | Ref.         | Ref.                | Ref.                | Ref.                | Ref.                | Ref.                |
| **95%CI**      |              |                     |                     |                     |                     |                     |
| **Tanner 2**   | 6.559        | 6.765               | 6.502               | 6.657               | 6.603               | 6.259               |
| **95%CI**      | (5.788 to 7.330) | (5.915 to 7.615)   | (5.635 to 7.369)   | (5.795 to 7.519)   | (5.73 to 7.947)     | (5.391 to 7.127)    |
| **Tanner 3**   | 13.315       | 13.138              | 13.157              | 13.075              | 13.823              | 13.414              |
| **95%CI**      | (10.643 to 15.987) | (10.055 to 16.221) | (10.194 to 16.120) | (10.199 to 15.951) | (10.643 to 17.002) | (10.518 to 16.309) |
| **Tanner 4**   | 14.130       | 14.083              | 14.307              | 13.153              | 15.276              | 13.892              |
| **95%CI**      | (9.046 to 19.213) | (8.446 to 19.719)   | (8.337 to 20.278)   | (7.541 to 18.764)   | (9.679 to 20.872)   | (8.259 to 19.525)   |
| **PPMH**       | 0.190        | 0.192               | 0.190               | 0.190               | 0.190               | 0.190               |
| **95%CI**      | (0.186 to 0.195) | (0.187 to 0.187)   | (0.185 to 0.195)   | (0.185 to 0.194)   | (0.186 to 0.195)   | (0.185 to 0.195)   |

### Table 5
Generalized linear model of CA and 5-fold cross-validation among girls (β (95%CI)).

|                | Total sample | Model 1 (n = 1405) | Model 2 (n = 1392) | Model 3 (n = 1324) | Model 4 (n = 1458) | Model 5 (n = 1394) |
|----------------|--------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| **Intercept**  | -4.524       | -4.606              | -4.563              | -4.633              | -4.352              | -4.461              |
| **95%CI**      | (-5.051 to -3.997) | (-5.198 to -4.013) | (-5.149 to -3.978) | (-5.221 to -4.046) | (-4.950 to -3.754) | (-5.045 to -3.877) |
| **Tanner 1**   | Ref.         | Ref.                | Ref.                | Ref.                | Ref.                | Ref.                |
| **95%CI**      |              |                     |                     |                     |                     |                     |
| **Tanner 2**   | -1.251       | -1.287              | -1.060              | -1.183              | -1.359              | -1.370              |
| **95%CI**      | (-2.029 to -0.473) | (-2.162 to -0.411) | (-1.927 to -0.192) | (-2.052 to -0.313) | (-2.237 to -0.480) | (-2.230 to -0.511) |
| **Tanner 3**   | 2.504        | 2.870               | 2.948               | 2.544               | 1.983               | 2.169               |
| **95%CI**      | (1.510 to 3.497) | (1.756 to 3.983)   | (1.843 to 4.052)   | (1.448 to 3.641)   | (0.855 to 3.111)   | (1.057 to 3.281)   |
| **Tanner 4**   | 8.752        | 8.659               | 9.037               | 8.948               | 8.362               | 8.741               |
| **95%CI**      | (7.123 to 10.381) | (6.823 to 10.495)  | (7.219 to 10.855)  | (7.128 to 10.768)  | (6.522 to 10.203)  | (6.950 to 10.531)  |
| **Tanner 5**   | 11.893       | 12.638              | 11.646              | 12.764              | 11.912              | 9.937               |
| **95%CI**      | (8.119 to 15.666) | (8.419 to 16.857)  | (7.472 to 15.820)  | (7.847 to 17.670)  | (7.829 to 15.994)  | (5.213 to 14.661)  |
| **PPMH**       | 0.158        | 0.159               | 0.159               | 0.160               | 0.156               | 0.158               |
| **95%CI**      | (0.152 to 0.165) | (0.152 to 0.167)  | (0.152 to 0.166)  | (0.153 to 0.167)  | (0.149 to 0.164)  | (0.150 to 0.165)  |

### Notes
- MAE: mean absolute error; PPMH: percentage of predicted mature height; Ref.: reference group; RMSE: root mean square error.
cross-validation were not statistically different compared to the coefficients obtained from the total sample, which indicates support for the stability of the predicted values in our EA equation. Additionally, the MAEs and RMSEs in the cross-validation were shown to be similar to that calculated from the total model, providing further support for the validity of the model developed on the total sample.

3.5. Relationship between CA and EA and PA

The relationships between levels of PA and CA and EA are shown in Table 6. Results indicate that, although there was a positive relationship between PA and CA across boys and girls, the magnitude of the relationship observed was small, with the largest correlation coefficient being 0.20 for boys and 0.23 for girls. The same pattern was also found in the relationship between PA and EA, with the largest correlation coefficient being 0.18 for boys and 0.20 for girls. Table 6 also includes correlations between PA and the discrepancy score (EA – CA). As can be seen, all PA variables except LPA in boys were negatively but weakly correlated with the discrepancy score in both genders, with the largest correlation observed for MVPA ($r_{boys} = -0.09, p < 0.001$; $r_{girls} = -0.12, p < 0.001$).

4. Discussion

In this large-scale cross-sectional study, we showed that a gender-specific age estimation equation, based on physical examination indicators, was able to provide an accurate estimation of age among Chinese school children between 7 and 12 years of age. Results from our cross-validation support both the accuracy and predictability of our equation. To our knowledge, this is the first and largest population-based study of age estimation using combined information on somatic growth (i.e., body height) and sexual maturity.

In a previous study, we have shown an estimation error margin of 0.64 ± 0.48 years between skeletal age (as estimated by the Greulich and Pyle method) and CA among Chinese school children. Estimations derived from the current study improved accuracy and showed an estimated value of 0.6 years observed across both genders in the current study. This suggests that physical examinations may offer an alternative, noninvasive, and inexpensive approach to estimating age when gold-standard methods, such as skeletal measures, are not available.

With respect to the levels of PA, we found a positive but small relationship between levels of PA and EA and CA for boys and girls. A similar pattern of correlations was observed for the relationship between PA and the estimated-chronological discrepancy scores. These findings indicate that although children’s PA is significantly related to the EA values, this relationship is substantively weak in the current study. One possible explanation is that the self-reported PA measure may have inflated this association. Future studies are needed to reassess this relationship using either objectively assessed fitness or physical performance measures to further validate the EA estimation equations.

The study has some notable strengths, including the large sample size (which is representative of the target population of school children) and the use of multiple sources of age information (which was built into the EA question), thus enhancing the validity of our approach. The inclusion of a PA assessment as part of the equation validation process also strengthens the study. The age estimation equation was developed using common physical indicators that can easily be ascertained in practice, without any special equipment. Thus, the process is sufficiently simple for widespread implementation in a variety of communities and settings.

The study also has some limitations. First, although we included a PA measure (C-CLASS), the use of self-reported measures may have diluted the relationship between PA and EA. In fact, the C-CLASS was shown to overestimate PA, especially in the VPA category among children. To reduce bias, future studies should consider objectively measured PA, including physical performance-based measures (e.g., speed, agility, strength, and endurance), because they are more relevant in studying growth and biologic maturation. Second, our age estimation equation was developed based on a sample of school children who may not be as athletically oriented as other young children in China. Therefore, the equations developed may not be directly applicable to a more athletic population of children. Finally, the precision of the established age equation
may be affected by the fact that we did not control for the potential confounding effect of diet and nutrition on biological maturation.

In the area of studying children’s PA and sports participation, age information is routinely required, for example, to verify age for proper placement in sports, to match opponents in competitive sports, and to better understand maturity-associated variation in physical performance.22,23 In this regard, the age estimation equation developed in this study has the potential to be used in applications such as age screening, matching, and placement in sports. Given the increasing prevalence of obesity, hypertension, and metabolic syndromes among school-age Chinese children,22,23 and with a growing emphasis on promoting PA among this population,24 our equation may be useful in identifying safe and age-appropriate vigorous-intensity activities, such as strengthening or bone-building exercises.

5. Conclusion

An age estimation equation based on physical indicators was shown to be accurate and valid in estimating age among Chinese school children 7–12 years old. The equations can easily be derived using common and accessible anthropometric measures and be applied in programs involving participation by school children in PAs and sports.

Acknowledgments

The study was supported by National Natural Science Foundation of China (81422040, 81172685); Ministry of Education New Century Excellent Talents (NCET-13-0362), Shanghai Science and Technology Commission (12411950405, 14441904004, 13QH1401800); The fourth round of Three-Year Public Health Action Plan (2015–2017) (GWIV-36); Shanghai Municipal Education Commission (D1502); The Ministry of Science and Technology (2010CB535000).

Authors’ contributions

LS participated in the analysis and drafted the manuscript; XS and FJ designed the study and helped to draft the manuscript; JZ and FO provided critical comments on the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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