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Prediction of adult height by Tanner–Whitehouse method in young Caucasian male athletes

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Summary

Background: Although the accuracy of final height prediction using skeletal age development has been confirmed in many studies for children treated for congenital primary hypothyroidism, short normal children, constitutionally tall children, no studies compared the predicted adult height at young age with final stature in athletic population.
Aim: In this study, the intention was to investigate to what extent the Tanner–Whitehouse (TW) method is adequate for prediction of final stature in young Caucasian male athletes.
Design: Prospective observational study.
Methods: Plain radiographs of the left hand and wrist were obtained from 477 athletic children (ranging in age from 8.0 to 17.9 years) who came to the outpatient clinic between 2000 and 2011 for adult height estimation, with no orthopedic trauma suspected. Adult height was estimated using bone age rates according to TW method. Height was measured both at baseline and follow-up (at the age of 19 years).
Results: No significant difference was found between the estimated adult height (184.9 ± 9.7 cm) and final stature (185.6 ± 9.6 cm) [95% confidence interval (CI) 1.61–3.01, $P = 0.55$]. The relationship between estimated and final adult height was high ($r = 0.96$). Bland–Altman analysis confirmed that the 95% of differences between estimated adult height and final stature lie between limits of agreement (mean $\pm$ 2 SD) (-5.84 and 4.52 cm).
Conclusion: TW method is an accurate method of predicting adult height in male normal-growing athletic boys.

Introduction

Adult height prediction is a common procedure in pediatric endocrinology, particularly when the stature of a child is unusual for its age (e.g. below 3rd percentile or above 97th percentile).[1] The prediction may reassure the family or indicate a need for laboratory tests to establish the cause of the unusual growth.[2] On the other hand, estimation of final stature may be applicable in pediatric exercise science for talent identification, selection and development[3] or assignment to specific sport at early age.[4,5] Stature can play a significant role in contributing to success in some sports (although certainly not in all cases, and is not the only factor) by offering certain natural advantages for short athletes in gymnastics, motorsport or weightlifting, while tall athletes have an advantage in basketball, volleyball and swimming.[6] Therefore, knowing how tall the young athlete will be as an adult could shape its sports carrier, training routine and/or positional role in particular sport.[5,7] Since children differ greatly in the timing and tempo of growth, an accurate method of estimating adult height needs to

incorporate an indicator of biological maturity,[7] particularly for youth athletes, where biological maturation is closely related to physical performance.[8] Methods of predicting adult stature that use skeletal age development to account for variation in biological maturity are the gold standard in the field.[9] Besides other methods, Tanner–Whitehouse (TW) technique of bone age determination seems to be valid procedure for prediction of adult height, with acceptable median errors and systematic objectivity.[1,10] Although the accuracy of final height prediction using TW method has been confirmed in many studies for children treated for congenital primary hypothyroidism,[11] short normal children,[12] constitutionally tall children,[13] no studies compared the predicted adult height at young age with final stature in athletic population. In this study, the intention was to investigate to what extent the TW method is adequate for prediction of final stature of young Caucasian male athletes.

Methods

Plain radiographs of the left hand and wrist were obtained from 477 athletic children who came to the outpatient clinic between 2000 and 2011 for adult height estimation, with no orthopedic trauma suspected. Radiographs were taken using the same projection and exposure parameters for the primary assessment of bone age.[14] All participants and parents were fully informed verbally and in writing about the nature and demands of the study. All subjects and parents gave their informed consent and volunteered to participate in the study with the approval of the University's Ethical Advisory Commission in accordance with the Helsinki Declaration. Subjects included in this study fulfilled the following criteria: (i) normal findings on the radiograph of the left hand-wrist with neither bone (including fracture) nor soft tissue abnormalities; (ii) no medical record of congenital disorder or developmental disturbance; (iii) active participation in sport for at least 2 years; (iv) boys aged >8 years and (v) return to follow-up at the age of 19 years for final stature measurement. A total of 342 cases were excluded: 157 cases due to gender difference, 51 due to poor film quality and 134 for no final stature measurement at follow-up. The final study group consisted of 135 boys ranging in age from 8.0 to 17.9 years, with a mean age of 12.5 years. The subjects represent a wide range of sport disciplines including basketball ($n=71$), soccer ($n=25$), volleyball ($n=14$), swimming ($n=12$) and other sports ($n=13$). Adult height at initial assessment was estimated using bone age rates according to TW method[15] by sports medicine specialist trained in radiology. The mean (SD) bone age ratings were 13.1 (2.7) years. Prediction method uses TW skeletal ages of the hand-wrist radiographs and baseline stature as predictors, while mid-parent stature was used as a correction factor. Height was measured both at baseline and at follow-up using stadiometer (Seca 216, Hanover, MD, USA) to the nearest 0.10 cm. Statistical analysis was performed using Student's *t*-test with Bonferroni correction. The relationship between estimated adult height and final stature was examined using Pearson's product–moment correlation coefficient. To find individual differences the Bland–Altman procedure has also been calculated and illustrated. *P*-values of <0.05 were considered to be statistically significant. Data were analyzed using the SPSS program (version 18.0) (SPSS Inc., Chicago, IL, USA).

Results

No significant difference was found between the estimated adult height (184.9 ± 9.7 cm) and final stature (185.6 ± 9.6 cm) (95% CI 1.61–3.01, $P=0.55$). The relationship between estimated adult height and final stature is presented in Figure 1, and the correlation coefficient was high ($r=0.96$).

Figure 2 displays difference in height between predicted and final height against average height, and shows considerable agreement between estimated adult height and final stature since the results of Bland–Altman analysis confirmed that the 95% of differences lie between limits of agreement (mean ± 2 SD) (−5.84 and 4.52 cm).

Differences between predicted and final adult height in athletic boys according to skeletal age groups are depicted in Figure 3. Mean final adult height was underestimated by ∼0.60 cm in boys aged 8–12 years, and by 0.73 cm in boys aged 13–17 years ($P=0.76$).

Discussion

This study verified the accuracy of TW method for predicting adult height in young male athletes, with significant correlation between predicted and final stature ($r=0.96$; $P<0.0001$), and acceptable degree of agreement according to the Bland–Altman procedure, with mean adult height was underestimated by 0.66 cm on average for whole sample.

Although the prediction of adult height is a useful tool in the diagnosis and treatment of abnormal growth in children and adolescents, there is a curiosity in the adult height of normal-growth children.[7] This is of notable importance for children engaged

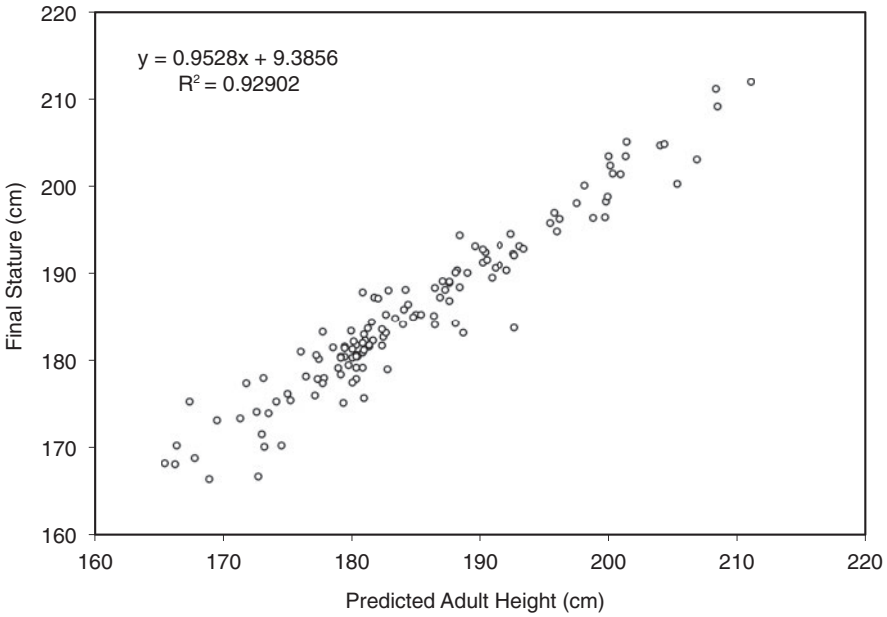

Figure 1. Correlation between predicted adult height by TW method and final stature in young male athletes ($n = 135$).

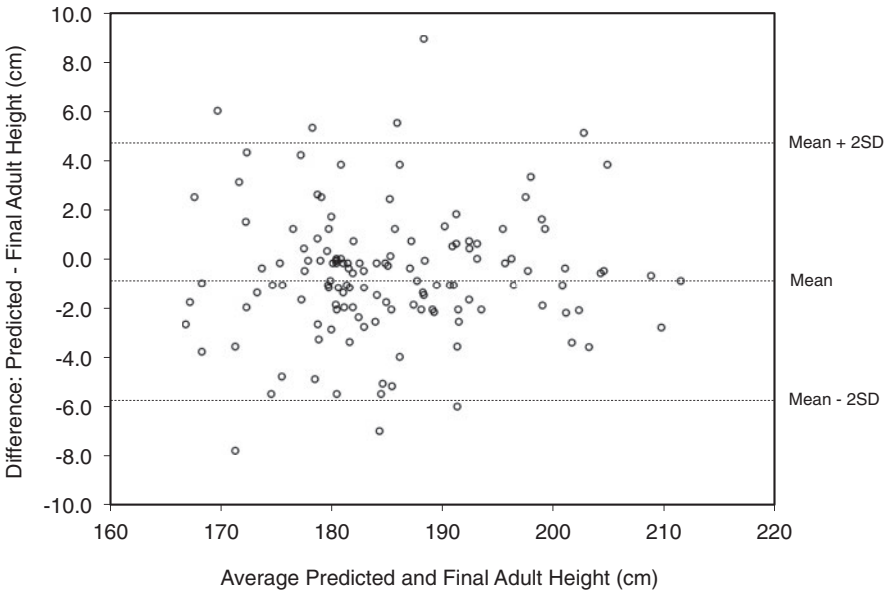

Figure 2. Difference between predicted and final adult height in boys ($n = 135$).

in sport because elite performance, as well as the performance of growing children and adolescents, partly depends on final stature.[16] An accurate estimation of adult height is thus important in the study of growth and performance for those involved in the guidance of young children in sport. Due to the differences among children in the tempo and timing of progress toward the mature biological state, precise method of estimating adult height needs to incorporate an indicator of biological maturity.[7] In the determination of physical development, skeletal age has proved to be a graded and accurate indicator, with different methods of predicting adult height in children via bone age assessment has been developed in the past (for review, see Roche and Sun).[2] Among others, TW prediction method of adult height uses TW skeletal ages of the hand-wrist, present stature and chronological age as predictors, and is applicable to children 6 years and older.[10] Several cross-validation studies shown median errors of ~3.0 cm that are smaller than those with other similar methods,[17]

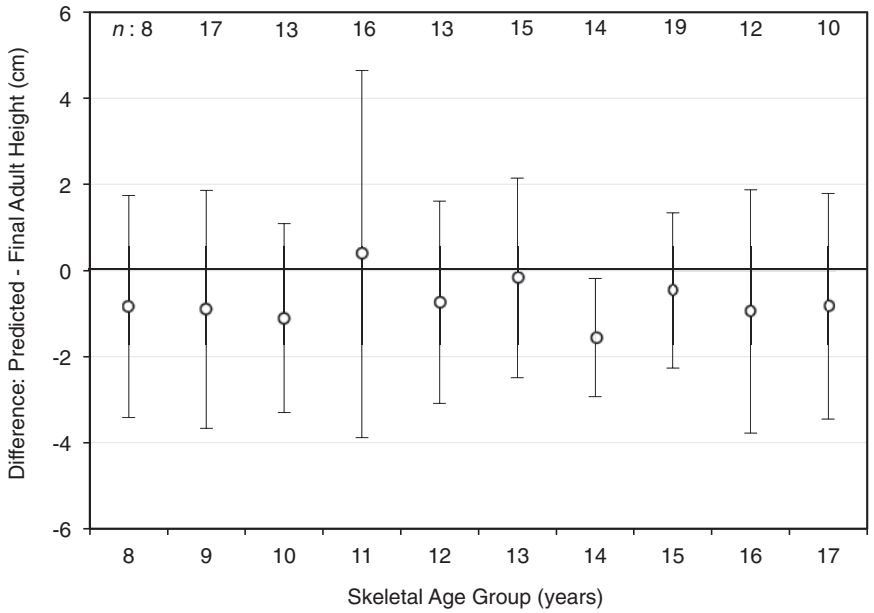

Figure 3. Mean difference (±SD) between predicted and final adult height according to skeletal age groups in athletic boys ($n = 135$).

with the multiple correlations for adult stature prediction in boys 8.0- to 17.5-year-old varied between 0.87 and 0.97.[15] Although validated in many studies for children free of growth-limiting disease[12,13,18] and children with abnormal growth,[11] the accuracy of TW method has not been confirmed in athletic children so far. This study reported a considerable agreement between estimated adult height and final stature in 135 athletic boys, with correlation coefficient ($r = 0.96$) superior to previous reports.[15,18] It seems that this method can predict final height ±2.59 cm 95% of the time in young male athletes. However, it should be noted that to obtain this degree of accuracy, correct protocols of measuring stature, taking hand-wrist radiographs and assessing skeletal age by specialist need to be followed. Still, despite these strengths, the present study is not without limitations, with size of the final study group could be considered partly limited. Large drop-out for the present study is mostly due to technical anomalies of the hand radiographs and poor retention of participants. Therefore, future studies on TW method for prediction of final stature would benefit from the use of automatic techniques to increase the quality of skeletal radiographs[1] and the use of more promising methods to overcome subjects loss to follow-up.[19] More number of good-quality studies are needed to add to the evidence base. In particular, continued study is needed to determine the accuracy of TW method for predicting adult height in female athletes.

Many reports show that the adult height estimation through skeletal age assessment may vary over time, between ethnic groups and between children in different geographic locations.[14] Specifically, highest accuracy of final stature prediction by TW method was reported when skeletal age was above 16 years in sample of normal children.[15] In the field of exercise science, an accurate prediction of adult height is needed for all bone age groups, particularly in the age range 12–15 years, the ages when sport participation among boys is generally high and talent identification and development for specific sport takes place.[3] For the present study, in the population of 135 athletic boys TW method gives a good estimation of final height up to the bone age of 17.9 years, with mean underestimation of 0.66 cm. The prediction of adult height seems to be skeletal age-independent since TW method uniformly estimated final stature for bone age groups 8.0–12.9 years and 13.0–17.9 years. Excellent results in predicting adult height for this study in both younger and older skeletal age groups favors TW method as valid and applicable for final stature estimation in athletic population throughout age continuum. This is probably due to the close similarity of study population to reference standards for bone age. In contrast, a Swiss group[18] reported acceptable estimation of final height in constitutionally tall boys up to the bone age of 13 years (mean overestimation of 1 cm), but TW method tended to overestimate height (up to 3.4 cm) in the older bone age groups. Authors suggested significant population differences and secular changes in skeletal maturation of Swiss children and British children from original sample upon which the TW

method was developed. It seems that due to variations between populations, an appropriate bone age rate for sample of children can be expected only if the population examined does not deviate from the population on which the scoring system was standardized.

In conclusion, TW method seems to predict adult height with a high degree of accuracy in young male athletes aged 8.0 years and older. The high correlation observed between predicted adult height and final stature can be considered as a cross validation of the TW method in this particular population. The prediction of adult height seems to be skeletal age-independent since TW method uniformly estimated final stature for both younger and older bone age groups of boy athletes.

Conflict of interest: None declared.

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