ANTHROPOLOGIE • XLII/2 • pp. 115–119 • 2004

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METHODS OF SKELETAL MATURITY ASSESSMENT – SOME CLINICAL ASPECTS

ABSTRACT: Bone age (BA) has an important place in the paediatric practice. The value of BA is the chronological age at which the 50th centile child has the maturity score of the given child. The skeletal maturity score (SMS) represents the fundamental value for bone maturity assessment. SMS is independent on influences such as secular growth changes, socio-economic class and ethnic group in contrast to the bone age. The methodological base of skeletal maturity assessment is a quantitative description of the radiograph of the left hand and distal part of the forearm. In contemporary clinical practice there are three most exact methods: GP (Greulich, Pyle 1959), TW2 (Tanner et al. *1975) and TW3 (Tanner* et al. *2001). Based on our own findings and long-term clinical experience, we recommend for common practice the GP method everywhere accurate evaluation is not required (ossification rate assessment or treatment control). For quite exact evaluation, that means especially for special clinical needs, the TW3 method should be used (scoring of multiple parameters gives results accurate to tenths of year). The mean difference between GP and TW3 is 0.1–0.2 years. The TW2 method may be considered as already obsolete – the difference between results of TW2 and TW3 methods is 1 year. It is given by the construction of the two methods: TW2 reference population came from the 1960s, TW3 method contains new standards of ossification of European and Euroamerican subpopulations, accelerated in comparison with TW2.*

KEY WORDS: Bone age – Skeletal maturity – TW2 method – TW3 method – GP method

INTRODUCTION

A skeletal maturity score is the fundamental datum for bone maturity measurement. It is simply a quantitative description of the X-ray film. For skeletal maturity assessment the hand and the distal part of the forearm are used because of easy positioning and a large number of bones in a small area.

Bone age (BA) is the chronological age at which bone maturity of a given child corresponds to the 50th centile. BA assessment presents 1) a significant part of differential diagnostics in all congenital and acquired chronic diseases associated with primary or secondary growth disorders, and also is 2) an important part of control of their therapy. Bone age, as the most accurate indicator of biological age and a unique source for exact prediction of final height, exerts its place in paediatrics in 3) making the growth diagnosis in healthy children with variable physiological growth patterns (familial short or tall stature, constitutional delayed or accelerated growth and puberty).

For many years significant differences between TW2 (Tanner *et al.* 1975) and GP (Greulich, Pyle 1959) methods have been observed. In 2001 a new method – TW3 (Tanner *et al.* 2001) was introduced in clinical practice. In modern paediatric workplaces where bone age is an indispensable parameter of biological age assessment, it is necessary to

Paper presented at the International Anthropological Congress "Anthropology and Society", commemorating the 60th anniversary of death of Dr. Aleš Hrdlička, held on May 22–24, 2003 in Prague, Czech Republic.

use recent and accurate methods of measurement. An issue of the day is which method is the optimal for skeletal maturity assessment.

GOALS

The Grant No. 7409-3 of Grant Agency IGA MZ 2003 whose the main objective is to increase the quality of diagnostics, control and modification of algorithms of the therapy of diseases associated with alteration of skeletal linear growth and skeletal maturity, has the following specific goals:

1. Comparison of three current exact methods of bone age assessment: British method TW2, American GP method and new British method TW3 using the data of the Czech population.
2. Recommendation of the "method of the first choice" for exact assessment of bone age with the use of radiographs of the hand and distal part of forearm.

MATERIAL AND METHODS

For exact evaluation of the methods, there were available 85 radiographs of the hand and of the distal part of the forearm of 31 early or late maturing boys and of 39 girls with *anorexia nervosa* (at age of 9.0–16.9 years). These radiographs were assessed by the three currently most accurate methods of skeletal maturity assessment – the GP, TW2 and TW3 methods (some of the individuals had more than one radiograph). None of the individuals was undergoing any drug therapy. All scans were independently read (using all three methods) by two evaluators (HK, IK).The GP method (still used both worldwide and in the Czech Republic) is the method of American authors Greulich and Pyle (1959). The method is based on a comparison of radiographs of the hand and distal part of forearm with photographic standards in GP atlas ("atlas matching"), specifically with 29 pictures for girls and 31 for boys. The models are made for separate bones and separate age categories of both sexes. According to various foreign works (Fry 1971, Buckler 1983, Kahleyss *et al.* 1990, Frisch *et al.* 1996, Oestreich 1997, Bull 1999, Aicardi *et al.* 2000) and also according to our long-time clinical experience (Krásničanová, Kuchyňková 2002a, b) the results of the GP method differ from those obtained by the method TW2. A fundamental objection against the use of GP method in clinical practice is an unsatisfactory (= too rough) age classification, which is e.g. insufficient for specific therapy control.

The TW2 method of British authors Tanner *et al.* (1975) has been considered the most precise one so far in most specialised workplaces. The method estimates the shape and size of twenty bones of the hand and forearm according to eight degrees (B to I), separately for each sex ("point scoring system"). There is a score to each maturity degree that amounts to values from 0 to 1,000 for adult ossification. Detected "skeletal maturity score" (SMS) is a fundamental value in the process of skeletal maturity assessment. Unlike bone age, the value of SMS is independent on such influences as secular trend, socio-economic or ethnic classification, etc. Total SMS according to tables of TW2 atlas corresponds to a relevant bone age with the precision of 0.1 year. TW2 method evaluates separately a "radius–ulna–short bones" compartment ("RUS", where short bones are metacarpals and phalanx of first, third and fifth fingers) and *ossa carpi* compartment ("CARP", all carpal bones). The skeleton of the hand and of distal part of forearm as a whole can be evaluated in the TW2 method by the sum of RUS values and CARP values (= TW20).

The method TW3 (Tanner *et al.* 2001), created by an international team under the leadership of Prof. Tanner, is an innovation of the TW2 method according to recent data of populations of Belgians (Beunen *et al.* 1990), Spaniards (Hernandez *et al.* 1991) and "European Americans" (Tanner *et al.* 1997). Method TW3 has been put in the practice of our workplace since June 2001 and according to our pilot study in individuals with physiological growth patterns and in patients with mental anorexia (Krásničanová, Kuchyňková 2002a, b) we assumed a very good convenience for the current Czech population. The method TW3 changes the interpretation of SMS values: compared to TW2 the age is decreasing when achieving the given SMS, for example by 0.9 year for girls and by 1.5 years for boys when achieving the score 1,000 (adult ossification). Norms of SMS contained in TW3 consider the known and repeatedly proven influence of secular trend on skeletal maturity in current European populations (Tanner *et al.* 2001), in TW3 for all age categories of girls and boys after the eighth year of life.

TABLE 1. Comparison of methods TW2, TW3 and GP.

Method of assessment ⇒ **Material ⇓**	**Differences of BA between TW2/RUS and TW3/RUS (in years)** **X ± SD**	**Differences of BA between TW3/RUS and GP (in years)** **X ± SD**
42 X-ray scans of girls (*anorexia nervosa*)	0.95 ±0.092 p=0.0025	0.01 ± 0.463 p=0.9694
43 X-ray scans of boys (early or late maturing)	1.12 ± 0.289 p=0.0016	0.03 ± 0.444 p=0.9310
Tanner *et al.* (2001)	1.0	0.1–0.2

Case 1 (Last data)

Height:		–2.7 SD
Pubic hair 3 (Mean age):		13.25 years
Testes 14 ml (Mean age):		14.5 years
Mother's menarche:		14 years
Bone age[1)] TW2/TW3/GP:		15.4/14.3/14.0 years
Biological age	⇒	cca 14.0–14.5 years

[1)] Bone age is depicted as "+"

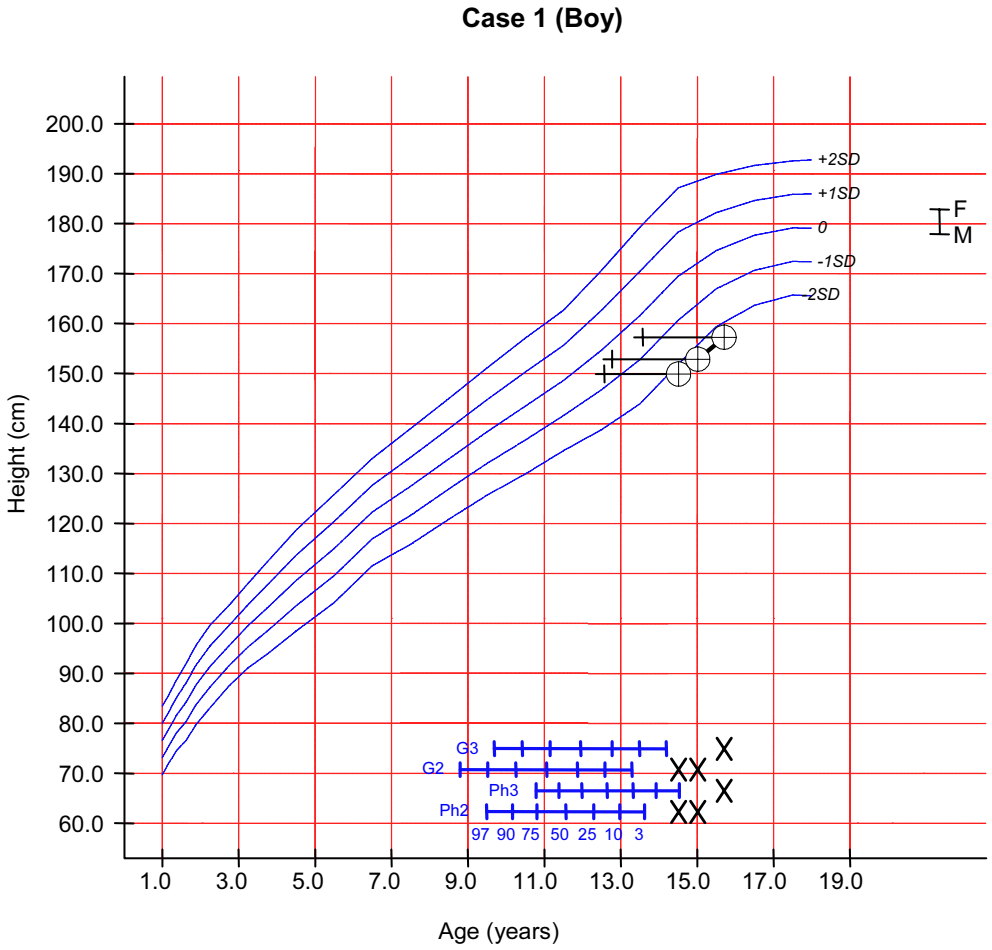

FIGURE 1. Constitutional delay of growth and puberty.

To compare the methods used for the bone age assessment, differences between results of each method were analysed for each radiograph. The differences were tested by standard paired *t*-test and quantified by descriptive statistic characteristics.

RESULTS

In our comparison of methods we observed that the difference between TW2 and TW3 values of bone age (in the RUS compartment) is in average 1 year (TW3 values lower by 0.95, 1.12 year respectively, see *Table 1*). The magnitude of the difference is given by the construction of these two methods – our results prove that our readings are quite correct. From the clinical point of view (multicentric studies, bone age diagnostics, therapy monitoring etc.) this difference is very significant (see *Figures 1, 2*). We proved that TW3 method reflects the secular trend of early biological maturation of contemporary Czech population in comparison with the past time.

On the other hand we found a very good agreement of values of bone age assessed by GP and TW3 methods (average difference only 0.01–0.03 year!). The reference

Case 2 (Last data)

Height:		+2.2 SD
Pubic hair 3 (Mean age):		12.4 years
Breast 3 (Mean age):		12.2 years
Mother's menarche:		12 years
Bone age[1)] TW2/TW3/GP:		14.2/13.2/13.0 years
Biological age	⇒	cca 12.5–13.0 years

[1)] Bone age is depicted as "+"

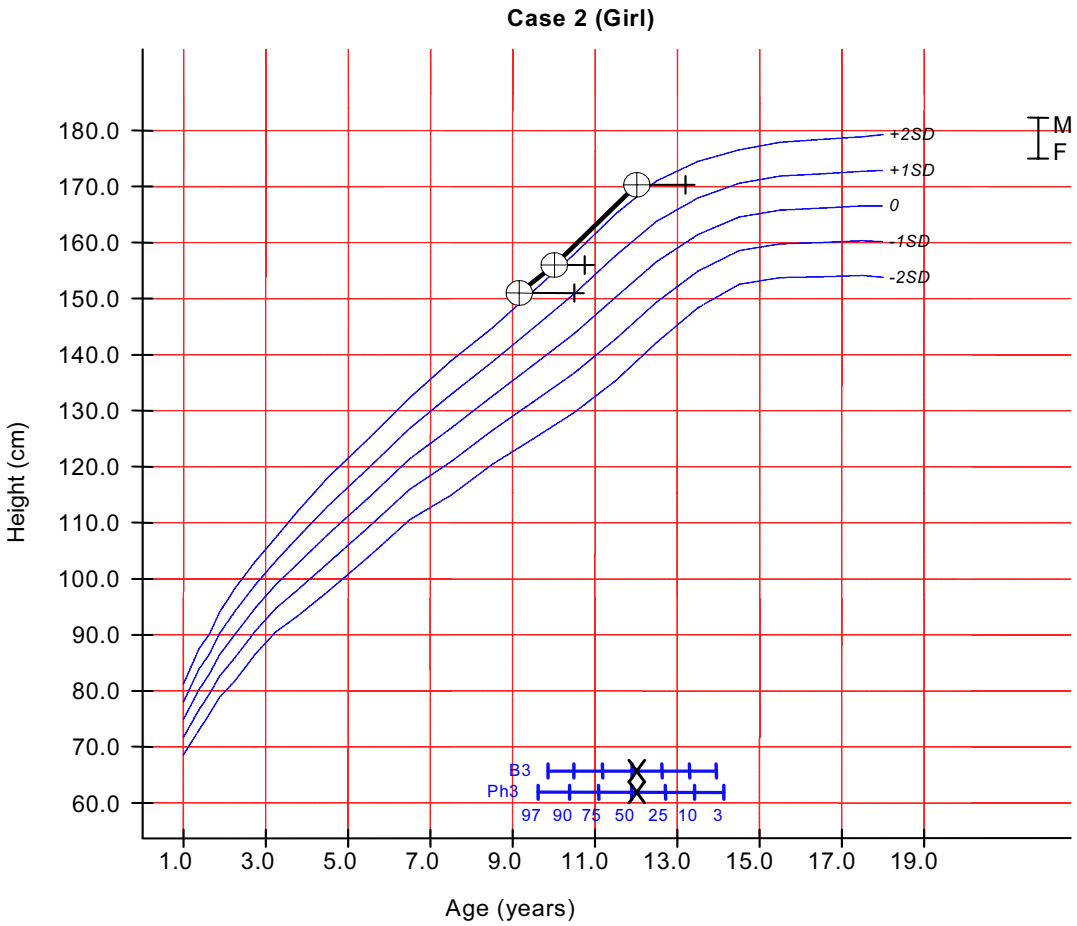

FIGURE 2. Constitutional acceleration of growth and puberty.

data of GP method came from higher socio-economic background. The difference of biological maturity between American and Czech populations has disappeared.

CONCLUSIONS

Based on these findings we recommend the GP method for common practice where accurate evaluation is not required. Despite the relatively old reference data, the GP method is still applicable for bone age evaluation.

For exact assessment in clinical practice (i.e. for ossification rate assessment or for treatment control) we prefer the TW3 method because it gives scoring of multiple parameters results accurate to tenths of year. We consider the TW3 method as the "method of first choice" in contemporary clinical practice and we also recommend abandoning the using of TW2 method.

The study was supported by Grant No. 7409-3 of Grant Agency IGA MZ 2003.

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