REVIEW ARTICLE

Comparative study between bone ages: Carpal, Metacarpophalangic, Carpometacarpophalangic Ebrí, Greulich and Pyle and Tanner Whitehouse2.

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Competing Interests
Authors have declared that no competing interests exists.

Abstract
We have carried out a review study in order to remind the pediatrician of the differences in bone age (EO) between the existing Greulich-Pyle (GP) or Tanner-Whitehouse 2 (TW2) methods compared to Ebrí ages: EO Ebrí-carpal (EOIC) metacarpophalangic (EOIMF) and Carpometacarpophalangic (EOICMF). The study was carried out in Spanish longitudinal casuistry "Andrea Prader". It comprises 160 healthy children: 73 males and 87 females, distributed by sex and age from 0.5 to 20 years. By obtaining the EO for each method, a comprehensive study can be carried out between them, and thus, observing if there are differences, being able to offer a quantification to the pediatrician for him to take them into account. In previous studies, the equations for obtaining the EO were expressed by the Ebrí methods. These quantifications are presented throughout this review.
In this way, the doctor will be able to know the equivalences to EO Ebrí, when he only has the EO of a child by the GP or TW2 methods. However, when the pediatrician obtains the EO with our method, no correction is necessary for a Spanish child since it has been obtained directly, and not through the filter of the two English and American methods. When the Ebrí method is applied to non-Spanish children, it is also convenient to assess these differences.
We observe how in women, GP has a tendency to overestimate, while Tanner and our methods tend to underestimate. In men, not only GP has a tendency to overestimate but also TW2 compared to our methods.
Quantifying these differences translated into months, it is observed how in TW2 women, even underestimating a month and a half with respect to GP, presents an overestimation of 3 months with respect to EOIMF, 4 months with respect to EOIC and 4.7 months with respect to EOICMF. GP presents differences of up to 6 months with respect to EOIC, 6.5 months with respect to EOICMF, and 5 months with respect to EOIMF.
In males, TW2 presents overestimations of EO of up to 4 months different from EOICMF, 5 months from EOIMF and EOIC, and about a month and a half from GP. Greulich and Pyle show minor overestimations, up to 3.3 months with respect to EOIMF, 3.7 months with respect to EOIC, and 2.7 months with respect to EOICMF.
Keywords: Comparative study between bone ages: Carpal, Metacarpophalangic, Carpometacarpophalangic Ebrí, Greulich and Pyle and Tanner Whitehouse2.

Introduction

Our method has been published (1) (2) and is already being used in different countries. It has also recently been presented at the Congress of the European Society of Medicine held in Vienna (3). In this review we do not want to prove its validity, which is already accepted. We would like to report bone age gaps and quantify them in regards to other methods such as Greulich and Pyle (GP) (4) and Tanner Whitehouse2 (TW2) (5) when applying them to the Spanish longitudinal casuistry "Andrea Prader" (6) In this sense, knowing these quantified lags we can observe the differences in the estimation of bone age, depending on whether we use one or the other method.

In Anglo-Saxon countries the American and English methods are preferably used. Our method presents an alternative to them, offering additional advantages such as the possibility of creating new casuistry that better reflects the characteristics of children in any country, thus being able to avoid these bone age gaps. As a result, if the basic methodology is applied to create new studies on populations in different countries, it would not be necessary to apply these corrections, since this method would reflect their own standards.

We have carried out a review in order to remind the pediatrician of the differences in bone age (EO) between the existing methods Greulich-Pyle (GP) or Tanner-Whitehouse 2 (TW2) compared to Ebrí ages. : EO Ebrí-carpal (EOIC) metacarpophalangic (EOIMF) and Carpometacarpophalangic (EOICMF). The study was carried out in Spanish longitudinal casuistry "Andrea Prader". It comprises 160 healthy children: 73 male and 87 female, distributed by sex and age from 0.5 up to 20 years. By obtaining the EO for each method, a comprehensive study between them can be carried out and observing if there are differences, we are able to offer the pediatrician a quantification to consider. In previous studies, the equations for obtaining the EO were expressed by the methods: EOIC and EOIMF (3). These quantifications are presented throughout this review.

In this way, the doctor will be able to know the equivalences to EO Ebrí, of the EO of a child provided by the GP or TW2 methods. However, when the pediatrician obtains the EO with our method, no correction is necessary for a Spanish child since it has been obtained directly, and not through the filter of the two English and American methods. When the Ebrí method is applied to non-Spanish children, it is also convenient to assess these differences.

Material and methods

The casuistry object of study includes 160 healthy children: 73 male and 87 female, distributed by sex and age from 0.5 to 20 years. The left hand radiographs were provided by the Andrea Prader Center, for their evaluation with our methods. It was endorsed and supported by the Government of Aragon (Spain) (6). It was also supported by the Endocrinology Unit of the Miguel Servet Hospital in Zaragoza and authorized by the Research Committee. In addition, a consent document was signed by the parents of children.

The children were carved and x-rayed in their left hand on each date of their birthday, being distributed by study groups. In a previous publication (1-3) we provided the table of the casuistry, the figures of the radiographs with the measurements used to obtain the Ebrí ossifying indexes and the EO, and the equations to obtain the prediction of adult height (PTA). These indexes are the result of the sum of the maximum diameters of the nuclei of each

region studied, measured in mm. The measurements can be made on the physical radiography with a nonius, as was done by the authors, or on digital radiography with the digital mouse (left hand Rx in dorsopalmar projection) downloaded from the Sanitary Intranet Network.

For the current statistical work, the statistical software package "Statistix" has been used, as well as the Excel program.

Results

In the attached table I, the differences between the chronological age (CA) of the child and his EO, for the various methods analyzed are shown in both sexes and by age groups from 0.5 to 20 years. These differences can be positive (they overestimate) or negative (they underestimate). An average of these differences has been made in all the analyzed methods, studying all the age intervals, in such a way that the mean obtained from these differences is the one that serves as a model to quantify these lags, once they are added or subtracted, when relating a foreign method in regards to ours. These differences are offered in fractions of years, however they can be translated into months. Thus, for example 0.25 years is equivalent to 3 months of lag.

Table I. Compative table of bone age differences between methods

	WOMEN					*MEN*				
AGE	***EOGP***	***EOTW2***	***EOIC***	***EOIMF***	***EOICMF***	***EOGP***	***EOTW2***	***EOIC***	***EOIMF***	***EOICMF***
0,5	0,07	0	-0,34	-2,3	-1,36	0,16	0	0,79	-0,04	-0,1
1	0,17	0	-0,33	-0,16	-0,87	0,1	0	0,63	-0,74	-0,33
2	0,07	0	-0,3	0,39	-0,06	-0,12	0	0,35	-0,54	-0,15
3	-0,02	0	-0,29	1,14	0,29	-0,08	0	0,06	0,39	0,14
4	0,01	0,24	-0,23	1,29	0,43	-0,04	0	-0,25	0,82	0,18
5	0,16	-0,42	0,16	1,24	0,68	0	-0,59	-0,38	1,07	0,24
6	0,03	-0,08	0,48	1,25	0,85	-0,07	-0,52	-0,39	0,99	0,22
7	0,18	0,32	0,95	1,44	1,18	-0,05	-0,51	-0,19	0,91	0,32
8	0,16	0,18	1,14	1,37	1,23	0	-0,22	0,07	0,82	0,42
9	0,23	0,62	1,28	1,23	1,28	-0,02	0,07	0,25	0,73	0,48
10	0,35	0,95	1,57	1,23	1,43	0,43	0,51	0,35	0,57	0,45
11	-0,25	1,22	1,55	1,13	1,39	0,39	0,48	0,45	0,44	0,46
12	0,48	1,34	1,37	0,92	1,19	0,51	1,04	0,7	0,47	0,63
13	-0,57	1,3	0,89	0,49	0,73	0,17	0,92	0,67	0,22	0,51
14	0,86	1,63	0,38	0,04	0,26	0,13	1,04	0,61	0,14	0,44
15	0,71	0,95	-0,61	-0,89	-0,7	0,18	1,28	0,3	-0,08	0,17
16	0,49	0,01	-1,53	-1,77	-1,59	0,34	1,45	-0,23	-0,62	-0,34
17	0,16	-0,98	-2,42	-2,63	-2,47	0,45	0,6	-1,04	-1,44	-1,15
18	-0,33	-1,98	-3,46	-3,6	-3,46	0,13	0,05	-1,91	-2,27	-2,01
19	-1,21	-3,03	-4,69	-4,87	-4,74	-0,44	-0,84	-2,62	-2,92	-2,71
20	-2,04	-4,04	-6,12	-6,18	-6,14	-1,28	-1,95	-3,88	-4,14	-3,97
MEDIA	**0,01**	**-0,15**	**-0,5**	**-0,43**	**-0,55**	**0,05**	**0,18**	**-0,27**	**-0,25**	**-0,18**

Age: years; EOGP: Greulich-Pyle Bone Age; EOTW2: Tanner Bone Age; EOIC: Carpal Bone Age; EOIMF: Metacarpophalangic Bone Age; EOICMF: Carpometacarpophalangic Bone Age; mean: average of the differences (in years) of all age groups and all bone ages analyzed. The differences can be positive or negative.

We observe how in women, GP has a tendency to overestimate, while Tanner and our methods tend to underestimate. In men, not only GP has a tendency to overestimate but also TW2 compared to our method.

Quantifying these differences translated into months, it is observed how in TW2 women, even underestimating a month and a half with respect to GP, it presents an overestimation of 3 months with respect to EOIMF, 4 months with respect to EOIC and 4.7 months with respect to EOICMF. GP presents differences of up to 6 months with respect to EOIC, 6.5 months with respect to EOICMF, and 5 months with respect to EOIMF.

In males, TW2 presents overestimations of EO of up to 4 months of difference from EOICMF, 5 months from EOIMF and EOIC, and about a month and a half from GP. Greulich and Pyle present minor overestimations, up to 3.3 months with respect to EOIMF, 3.7 months with respect to EOIC, and 2.7 months with respect to EOICMF

Discussion

Bone maturation for Martí Henneberg is the best general indicator of biological development available in the human species. Bone age expresses this process of maturation, requiring simple radiological studies to determine it, using the left hand radiography, which is the preferred anatomical region in the opinion for most of the authors (7)

The evaluation of the person´s growth and the determination of the most intense periods that occur during maturation provide important clinical information for the interdisciplinary diagnosis, especially for the pediatric endocrinologist, to control the normal growth of the child, as well as to serve as a modern method of predicting adult height and to check the response to suitable treatment for pathologies that may accelerate or retard normal growth. The calculation of bone age is interesting not only for the pediatrician, but also for sports medicine in order to avoid the negative influences of excessive training on the growth and maturity of children and young people. It is also of interest in forensic medicine, when they analyze severely damaged human remains, presumably belonging to children or young people. All these considerations have been accredited by several authors (8-11).

Although there is concordance of our indexes with the main methods of studying bone age, that is GP and TW2 methods, our numerical method has an advantage over the morphological approach of Greulich, since it relativizes the asynchronies and the own subjectivity of the doctor when choosing the most similar Rx of the American Atlas in regards to that of the child under study. And in regards to Tanner, it saves the difficult interpretations that occur in the last stages when giving the scores, among other points (12).

Ebrí developed the study's methodology in 1992 and 1993 comparing a longitudinal Swiss population to a Spanish population by using the methods of GP with those of TW2 (13-14). In 1996, Ebrí (15) applied his Swiss longitudinal population indexes, the same bone Rus TWII studied, by comparing the two methods, checking their compatibility. He found a greater simplicity of the metacarpalphalangeal bone assessment index compared to the complex methodology of the English author. A year later Ebrí (16), in the same Swiss population of 10-22 years of age, made a comparative study of bone ages of these children by different methods: carpal Tanner, Tanner-Rus, Ebrí carpal, Ebrí metacarpophalangic, and Greulich-Pyle.

He checked the concordance between them, although detecting differences, since each methodologically behaved differently. The same bones that TWII-Rus analyzed were preferred, as they were more useful than the carpals, and correlated better with pubertal changes, being most predictive of adult height (3).

It is known that there are genetic, racial, and exogenous environmental differences between population groups with respect to EO, in such a way that each racial group has its own bone age (16) regardless of the differences in the technique itself due to the limitations of each method. In this regard, there have been authors who have tried to adapt these foreign methods to a Spanish child, such as Hernández, who in 1991 published a TW2 atlas adapted to the Spanish population (17) or Tanner himself when in 2001 he standardized the Rus and Carpal system for a North American child, naming it TW3 (18,19). For this reason, and given that there are these racial and technical differences, we have considered convenient to estimate the EO lags when these foreign methods are used with respect to ours in Spanish children, also given that in many studies carried out only these foreign EO are available. Let´s also remember the recommendations of different authors such as García Almansa, Palacios, Ferrández Longás, Hernández, Sarría and Ebrí Torné (20, 21), that each country should have its own anthropometric and bone age standards.

Let´s remember remark here that the ideal scenario would be to use an aseptic method for obtaining bone age for each country, generated according to the racial, genetic-environmental characteristics of their own children.

Our general method for obtaining bone age (EO) (1-3) offers this possibility of creating standards specific to each country or racial group without the limitations of indirectly assessing the EO of one population with the standards of another, as occurs with the aforementioned methods, despite to correction attempts by the authors reviewed. In this way, the standards created in future prospective studies would only translate these racial-environmental differences, but not the purely technical ones due to the limitations of these methods developed in foreign children and then "transplanted", when applied to the study of other children, we no longer have a need for correction, applying these differences outlined.

In Table II, we recall the general differential characteristics between the Ebrí method and the GP and TW2 methods (22)

Table II. Comparison of greulich-pyle, tanner whitehouse and ebrí bone age calculation methods. differences between them

A-Greulich and Pyle:

1. Morphological, qualitative, and approximate method for bone age calculation.
2. We cannot discard the subject approach of the explorer in regards to an accurate diagnosis. In order to minimize this problem, the serial observations of a single patient have to be done by the same observer.
3. Frequent asynchronies in early ages, which hinder an accurate diagnosis of the bone age.
4. Created for American child, with early maturation. As a result, it can yield gaps of false advancement of bone age in Latin child.
5. It uses chronological age as the measurement unit, but not all children are equal.
6. Greulich & Pyle atlas only offers the average value, but not the normal margin expressed in percentages or standard deviations, within which a radiography cannot be considered as pathological.

B-Tanner-Whitehouse:

1. British numerical method, created for Anglosaxon child.
2. Technically difficult. It requires the observer a great experience.
3. It assigns values to the ossifying bones in the late stages of the carpal with a doubtful interpretation, due to large punctuation breaks by overlapping cores and to a non-strict universality of some of the index described, implying differences of up to two years (Andersen 1971).
4. Gaps for Latin child, generally providing false advancements of the bone age

C-Ebrí:

1. Numerical method. Applicable to any child, especially Latin American child.
2. For these children it does not require to correct gaps in bone age in regards to the two methods.
3. Relativizes the appearance of asynchronies, as it provides an average value of all the bones and its maximum lengths.
4. Software method that enables a direct and fast calculation of the bone age and adult height.
5. Download the software program for free at: **www.comz.org/maduracion-osea**

Conclusions

When the pediatrician only has the EO of a child by the GP or TW2 methods, if he knows these differences in EO between methods, he can apply these to the EO Ebrí. However, when the pediatrician applies the EO obtained by our method, a correction will not be necessary for a Spanish child, since the EO has been obtained directly, and not through the filter of the two English and American methods. When the Ebrí method is applied to non-Spanish children, it is also convenient to assess these differences

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