Skeletal age and biological maturity in Japan Professional Soccer League U15 category players

Ryo Takahara^{1*} and Shumpei Miyakawa²

¹ *Tsukuba Sports Medicine and Health Science Center, University of Tsukuba Hospital, 2-1-1 Amakubo, Tsukuba, Ibaraki 305-8576, Japan*

² *Faculty of Health and Sport Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8575, Japan*

Received: January 9, 2019 / Accepted: July 3, 2019

Abstract One method of determining a person's biological maturity involves evaluating their bone maturity. Differences in physical abilities among athletes during the growth period are thought to be strongly influenced by differences in bone maturity. Thus, it is necessary to understand biological maturity when selecting athletes. Accordingly, this study looks at the biological maturity of young Japanese soccer players in the Japan Professional Soccer League. In total, subjects included 282 male soccer players (mean age, 12.4 ± 0.7 years; mean height, 154.0 ± 9.1 cm) in the J-League Academy, 2007–2012. Results show that the TW2-RUS method (Japan) revealed no significant difference ($t = 1.012$, $df = 277$, ns); however, the TW3-RUS method revealed a significant difference ($t = -4.075$, $df = 281$, $p < 0.05$) for chronological age vs skeletal age in t-test. The breakdown of biological maturity according to the TW2-RUS method (Japan) was as follows: mature, 3 persons; early maturing, 45 persons; average, 196 persons; and late maturing, 38 persons. The breakdown of biological maturity according to the TW3-RUS method was as follows: mature, 3 persons; early maturing, 53 persons; average, 132 persons; and late maturing, 94 persons. The chi-square test revealed a significant difference ($p < 0.001$) between the TW2-RUS method (Japan) and the TW3-RUS method. Our results suggest that it is appropriate to use the TW2-RUS method (Japan) to evaluate skeletal age. With regard to biological maturity, contrary to prior research in Europe and America, a high proportion of our athletes had average biological maturity.

Keywords : skeletal age, biological maturity, soccer

Introduction

Bone maturity is a known indicator of a person's individual biological maturity. The report of Todd detailing human maturity was the first of its kind¹⁾. Greulich and Pyle reported on bone maturity using a visual method with X-ray images²⁾. A widely used method for evaluating bone maturity today involves evaluating bone maturity using the Tanner and Whitehouse (TW) method, which uses bone evaluation points (scores) as described by Tanner et al.³⁾. The TW method has three types of scoring: 20-bone, radius-ulna-short bone [RUS], and carpal. Tanner recommends bone maturity evaluations using the RUS method. Tanner et al. twice modified the TW method^{4,5)}. There currently are reports up to TW3⁵⁾. The TW2 method was created based on data for white English children in the 1950s. In Japan, Ashizawa et al. studied the relationship between the TW2 method and chronological age using Japanese children as subjects⁶⁾. In that report, for boys and girls, the mean bone age exceeded the mean chrono-

logical age, so the evaluation scores were greater than the chronological age. Murata et al. reported on the Japanese Bone Maturity Atlas method, called the "TW method (Japan)," which was based on the TW2 method, to more accurately evaluate Japanese bone maturity⁷⁾. The Japanese Childhood Bone Age Atlas was recently revised⁸⁾. When the TW2 (Japan) and TW3 methods are used to evaluate bone age, the evaluation of the bone maturity stage with the RUS score is the basis for the skeletal age evaluation. In the TW method, each bone is given a biological weight in the determination of maturity stage. For the RUS score in the TW method, if the total is 100%, then the radius and ulna are 20% each; the metacarpal I, proximal phalanx I, and distal phalanx I are 6.7% each; and each of the other bones is 5%. The relative weights of the radius and ulna are large, and a change in maturity stage can easily have a large effect on the skeletal age evaluation.

Dvorak et al. measured the bone maturity and skeletal age of players up to 17 years of age who participated in international soccer competitions run by the International Federation of Football Association⁹⁾. In this report, skeletal age was used to check whether age was misrep-

*Correspondence: takahara.ryo.fw@un.tsukuba.ac.jp

resented in the players who participated in the competitions. Le Gall et al. reported on bone maturity and injuries of players up to 14 years of age at the France National Academy. In one of these reports, among athletes who did not receive pro contracts, a large proportion were early maturing¹⁰. Figueiredo et al. reported on the relationship between biological maturity and physical ability for athletes representing Portugal. Specifically, differences in athletic ability at the ages of 11–14 years are caused by differences in biological maturity, but these differences in athletic ability disappear with growth¹¹. Carling et al. reported on a bone maturity survey of 158 elite young soccer players (age 13.4 ± 0.4 years), and a large percentage with early maturity were selected¹². Malina et al. reported on the growth of soccer players aged 10.7–16.5 years in Portugal. This study reported that early maturing players were more frequently selected. It was also reported that, at the time of selection, late maturing players may be less likely to be selected than early maturing players due to difference in athletic ability¹³. Among Japanese soccer teams, athlete selection is often performed when players reach the ages of junior (U12), junior youth (U15), and youth (U18). For U15 player selection, there are sometimes many respondents. In the U15 athlete selection, Japanese male players 11–12 years old are just prior to the peak (mean, 12.5–13.0 years) in the growth rate of Japanese¹⁴. Since early and late maturing athletes are selected using the same conditions, it is possible that the late maturing athletes, with less athletic ability, are less likely to be selected. Matsuoka reported, with regard to the bone maturity score for boys in Britain and Japan, that in the group of Japanese boys 12 chronological years of age showed significantly higher values. This shows that British and Japanese boys grow at the same rate at 7–12 years of age. However, at 12–14 years of age, Japanese boys grow much faster than British boys¹⁵. After 14 years of age, Japanese boys tend to show a somewhat accelerated growth rate but no significant difference between the bone maturity score and the final development condition. Hirose and Hirano studied the percentages of players on soccer teams sorted by chronological age into 3-month categories¹⁶. In this report, players born in April through June had the highest percentage, and those born in January through March were the lowest. Knowing the biological maturity of soccer players is important in their selection. Also, the most common timing for player selection in Japan is age 11–12 years. This is just prior to the peak (mean, 12.5–13.0 years) in the growth rate of Japanese, so it is a period with extremely large individual differences. To ensure fair U15 player selection, it is necessary to accurately know the biological maturity. One can say that it is necessary to predict the future growth rate. However, there has been little prior research related to bone maturity surveys on young Japanese male soccer players. Therefore, the purpose of the present study is to study the biological maturity of young Japanese male soccer play-

ers who belong to professional soccer teams in Japan.

Subjects and Method

Subjects

The subjects were 282 individual male soccer players (age 12.4 ± 0.7 years, height 154.0 ± 9.1 cm) in the J-League Academy, 2007–2012. The present study was conducted in accordance with the ethical standards formulated in the Declaration of Helsinki and was approved from the Athletics Ethics Committee of the Graduate School of Comprehensive Human Sciences of the University of Tsukuba (problem number: Sports Science 25-69), and informed consent was obtained from all participants and their guardians before data collection.

Method

Survey content

We surveyed bone maturity and skeletal age.

Survey items

We evaluated bone maturity from simple X-ray frontal views of the left arm joints.

Bone maturity score calculation method

Bone maturity was evaluated by an expert with more than 30 years of experience. For the actual evaluation of bone maturity, simple X-ray images were read two times. The bone maturity evaluation was based on simple X-ray images of the left arm joints (including the distal forearm, hand joints and hand). Degree of synostosis of the epiphyseal line of the target bones (13 bones) was classified into nine levels (A–I) based on the Japanese Childhood Skeletal Age Atlas⁷.

Skeletal age calculation method

Skeletal age was calculated using bone age conversion charts for the TW2-RUS method (Japan)⁶ and the TW3-RUS method⁵.

Classification method according to differences in bone maturity

To classify biological maturity, we used the method of Malina et al.¹³. Compared to chronological age, a skeletal age of at least +1.0 year(s) was called early maturing, less than +1.0 year(s) and at least -1.0 year(s) was called average, and less than -1.0 year(s) was called late maturing. If synostosis was complete, the bone was considered mature.

Statistical analysis methods

We used the paired t-test to compare skeletal age according to the TW2-RUS method (Japan) and the TW3-RUS method with chronological age. We studied the correlation between chronological age and skeletal age by the TW2-RUS method (Japan) and the TW3-RUS method

using Pearson's correlation coefficient. The distribution of the degree of maturity of the TW2-RUS Method (Japan) and TW3-RUS Method was compared by chi-square testing and analysis of residue was performed. In all cases, the significance level was set to <5%.

Results

The maximum value of the RUS score when evaluating bone maturity was 1000 points, minimum was 259 points, mean was 465.2 ± 155.5 points, and median was 408 points. The 75th percentile value was 557 points, 50th percentile value was 408 points, and 25th percentile value was 351 points (Table 1). For skeletal age with the TW2-RUS method (Japan), the mean was 12.5 ± 1.3 years, maximum was 15.5 years, minimum was 8.9 years, and median was 12.4 years. The mean difference between chronological age and skeletal age according to the TW2-RUS method (Japan) was 0.7 years. For skeletal age using the TW3-RUS method, the mean was 12.1 ± 1.8 years, maximum was 16.5 years, minimum was 8.5 years, and median was 11.7 years. The mean difference between chronological age and skeletal age according to the TW3-RUS method was 1.2 years (Table 2). To examine the difference between chronological age and skeletal age according to the TW method, we used the paired t-test. For chronological age and skeletal age with the TW2-RUS method (Japan), no significant difference was found ($t = 1.012$, $df = 277$, ns). For chronological age and skeletal age with the TW3-RUS method, a significant difference was found ($t = 4.075$, $df = 281$, $p < 0.05$). To investigate the relationship between chronological age and the TW2-RUS method (Japan) or between chronological age and the TW3-RUS method, we performed correlation analysis. A positive correlation was seen between chronological age and the TW2-RUS method (Japan) ($r = .664$, $p < 0.001$) (Fig. 1). Between chronological age and the TW3-RUS method, a positive correlation was also seen ($r = .699$, $p < 0.001$) (Fig. 2). The breakdown of biological

maturity based on the TW2-RUS method (Japan) was: adult, 3 persons; early maturing, 45 persons; average, 196 persons; and late maturing, 38 persons. The breakdown of biological maturity based on the TW3-RUS method was: adult, 3 persons; early maturing, 53 persons; average, 132 persons; and late maturing, 94 persons. The chi-squared test revealed a significant difference ($p < 0.001$) between the TW2-RUS method (Japan) and the TW3-RUS method. When we performed difference analysis, we saw that the TW3-RUS method gave a larger evaluation for late maturing (Table 3).

Discussion

To study the skeletal age of young Japanese male soccer players, we used correlation analysis and the paired t-test between chronological age and each TW method. We studied the mean difference between chronological age and TW method. In the correlation analysis, for chronological age and the TW3-RUS method, we found a positive correlation ($r = .699$). This result was slightly higher than the positive correlation for chronological age and the TW2-RUS method (Japan) ($r = .669$). Using the paired t-test, a significant difference was found between chronological age and the TW3-RUS method. For the average value of the difference between chronological age and skeletal age by TW method, the mean difference for the TW3-RUS method was 1.2 years versus 0.7 years for the TW2-RUS method (Japan). In Japan, there were intergenerational disparities in physique due to post-war food difficulties and the subsequent improvement of food supply. However, in Japan after 1986, there is no intergenerational difference in bone maturation, and it has been possible to evaluate growth over the long term. In the TW3 method the RUS score shows a delay of about 6 months in boys in the chronological age group of 10–12 years, of about 3 months in the 13–14 years of age category, and as early as 6 months for the 15–16 years of age group compared to the TW2 method according to Matsuoka et al.¹³⁾ Based on

Table 1. RUS Score

	Average	Max	Min	Median
RUS_score	465.4±155.5	1000	259	408

Table 2. Comparison of chronological age and skeletal age

	Average(age)	Max(age)	Min(age)	Median(age)	average difference for
CA	12.4±0.7	14	11	12.4	
TW2JPN_SA	12.5±1.3	15.5	8.9	12.4	0.7
TW3_SA	12.1±1.8 *	16.5	8.5	11.7	1.2

* vs CA $p < 0.05$

Fig. 1 Chronological age vs TW2 (Japan)_skeletal age

Fig. 2 Chronological age vs TW3_skeletal age

Table 3. Method & biological maturity classification

	biological maturity				total	χ^2
	adult	early	average	late		
TW2JPN_SA	3(1.1)	45(16.0)	196(69.5)	38(13.5)	282	*
TW3_SA	3(1.1)	53(18.8)	132(46.8)	94(33.3)	282	

*:P<0.001

the above, when evaluating the skeletal age and biological maturity of young Japanese soccer players, one might be able to say that it is effective to use the TW2-RUS method (Japan), the same method used to evaluate Japanese persons in general. With regard to biological maturity, based on skeletal age according to the TW2-RUS method (Japan), we classified biological maturity according to the classification method of Malina et al. The studies of Carling et al. and Malina et al. reported a high percentage of early maturing players among young soccer players^{12,13}. However, in the present study, putting together the mature and early maturing players, the percentage was only 19.9%, not even one fifth of the total. On the other hand, 13.5% of the players were late maturing, which is slightly less than the early maturing players. Most of the subjects (69.5%) in the present study were classified as average maturity. Thus, it is not always true that the selection of young Japanese soccer players focuses on early maturing athletes. However, among the subjects, three showed complete maturity. Malina et al. reported that, in the selection process, early maturing players with high physical ability were likely to be selected, whereas late maturing players were not¹⁴. Among the players who were subjects this time as well, when players were selected, there was a high chance for players with physical strength to be chosen.

Conclusions

Here we studied skeletal age evaluation methods and biological maturity using young Japanese soccer players as subjects. As an evaluation method for skeletal age, the TW2-RUS method (Japan) is an appropriate evaluation method for young Japanese male soccer players. We also found that, regarding the biological maturity of young Japanese soccer players in the J-League Academy, a high percentage of players had average maturity, a finding that is different from what was found in prior studies in Europe and America.

Conflict of Interests

The authors declare no conflicts of interest associated with this manuscript.

References

- 1) Todd T. 1937. Atlas of skeletal maturation. Part 1, the hand. St Louis: Moseby and Co.

- 2) Greulich WW and Pyle SI. 1959. Radiographic atlas of skeletal development of the hand and wrist, 2nd ed. Stanford University Press, California.
- 3) Tanner JM, Whitehouse RH, Marshall WA, Healy MJR and Goldstein H. 1975. Assessment of skeletal maturity and prediction of adult height (TW1 method). New York: Academic Press.
- 4) Tanner JM, Whitehouse RH, Cameron N, Marshall WA, Healy MJR and Goldstein H. 1983. Assessment of skeletal maturity and prediction of adult height (TW2 method). 2nd ed. New York: Academic Press.
- 5) Tanner JM, Healy MJR, Goldstein H and Cameron N. 2001. Assessment of skeletal maturity and prediction of adult height (TW3 method). 3rd ed. London: WB Saunders.
- 6) Ashizawa K, Asami T, Anzo M, Matsuo N, Matsuoka H, Murata M, Ohtsuki F, Sato M, Tanaka T, Tatara H and Tsukagoshi K. 1996. Standard RUS skeletal maturation of Tokyo children. *Ann Hum Biol* 23: 457-469.
- 7) Murata M, Matsuo N, Tanaka T, Ohtsuki F, Ashizawa K, Tatara H, Anzo S, Sato M, Matsuoka H, Asami T and Tsukagoshi K. 1993. Atlas of Japanese standard skeletal maturation. Tokyo: Kanehara Syuppan (in Japanese).
- 8) Tanaka T, Anzo S, Sato A, Sato M and Matsuoka H. 2011. Japanese childhood bone age atlas. Tokyo: Medical Review, Inc (in Japanese).
- 9) Dvorak J, George J, Junge A and Hodler J. 2007. Application of MRI of the wrist for age determination in international U-17 soccer competitions. *Br J Sports Med* 41: 497-500.
- 10) Le Gall F, Carling C, Williams M and Reilly T. 2010. Anthropometric and fitness characteristics of international, professional and amateur male graduate soccer players from an elite youth academy. *J Sci Med Sport* 13: 90-95.
- 11) Figueiredo AJ, Gonçalves CE, Coelho E Silva MJ and Malina RM. 2009. Youth soccer players, 11-14 years: Maturity, size, function, skill and goal orientation. *Ann Hum Biol* 36: 60-73.
- 12) Carling C, Le Gall F and Malina RM. 2012. Body size, skeletal maturity, and functional characteristics of elite academy soccer players on entry between 1992 and 2003. *J Sports Sci* 30: 1683-1693.
- 13) Malina RM, Reyes MEP, Eisenmann JC, Horta L, Rodrigues J and Miller R. 2000. Height, mass and skeletal maturity of elite Portuguese soccer players aged 11-16 years. *J Sports Sci* 18: 685-693.
- 14) Matsuoka H, Sato K, Sugihara S and Murata M. 1999. Bone Maturation Reflects the Secular Trend in Growth. *Horm Res* 52: 125-130.
- 15) Matsuoka H. 2017. Evaluation of biological development with the Tanner-Whitehouse 2 bone maturity score. *J Tokyo Wom Med Univ* 87: E48-E53.
- 16) Hirose N and Hirano A. 2012. The bias toward biological maturation through the talent selection in Japanese elite youth soccer players. *Int J Sport Health Sci* 10: 30-38.