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Estimating Passport Age from Bone Age among Youth Football Players: A Fallacy

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Age-group competitions are common to virtually all youth sports. Basic to such groupings is accurate reporting of ages. For most of the world, recording the date of birth is a routine component of health care at this time and is a legal record in official demographic and government documents. In some parts of the world births do not occur in hospitals or other health centers, and birth dates must be reported to establish legal status or are required by law. In such instances, there may be some length of time between a birth and its actual reporting. In some areas, there may also be a high rate of non-reporting (i.e., birth certificates or records are not available).

The integrity of age-group sport competitions is based upon the assumption that reported ages are accurate and records of age (e.g., birth certificates or passports - “passport age”) are valid. Nevertheless, problems with accurate reporting of age appear on a regular basis in youth sports. The 1992 Little League Baseball championship was forfeited by a team from the Philippines for use of illegal and overage players (Time Magazine 28 Sept 1992). A team from the New York City region was disqualified from the 2001 Little League championships for using an overage player; there was a two-year discrepancy between the official birth record and that provided to league officials (Sports Illustrated 3 Sept 2001). In the same year, teams were banned from the Asian Youth U-16 Championships for using overage players (Sports Illustrated cnnsi.com, 10 May 2001). More recently, FIFA used MRI (magnetic resonance imaging) to estimate the bone age of the hand-wrist among participants at the FIFA U-17 Championships in Finland in 2003. On the other hand, altering birth certificates to make a child older in order to qualify for a competition in sports with a lower age-limit is also a possibility (e.g., artistic gymnastics for females).

Use of Biological Age to Verify Chronological Age

The case of the Asian Youth U-16 football championship is relevant to the present discussion.

> "The AFC introduced x-rays to determine the age of players at the Vietnam tournament after it found that teams were using players above the permitted 16 years of age. X-rays can be read to determine bone age. …'When we put the bone age against the passport age we found players who were supposed to be under 16 were actually 19 or 20.'" (www.CNNSI.com, 2001)

The comment begs the following question: **Is a measure of bone (biological) age a valid indicator of passport age?** Passport age is presumably based on a legal birth certificate (i.e., the difference between date of birth indicated on a passport and date of observation). In age-group competitions, date of observation refers to FIFA-specified cut-off points that define an age group. For example, a player born between 1st January 1989 and 31st December 1989 is classified as U16 for 2005 competitions.

The issue of chronological (calendar) age versus biological age has a long history in studies of growth and maturation. First mention of bone age as potentially useful in grouping boys for sport dates to 1908, 12 years after Wilhelm Roentgen discovered the X-ray.

There are several indicators of biological age or biological maturity, but some are useful only during adolescence (e.g., stage of sexual maturity reflected in pubic hair or genital development, volume of the testes, voice change, facial hair, timing of maximum growth during the growth spurt, each has limitations). There is considerable variation in the chronological ages at which these indicators are attained. Some boys may begin the development of pubic hair at 10 years of age while others may not begin the process until 13 years of age. Boys who begin pubic hair development at different ages can also vary considerably in size, strength and power. There is similar variation in ages at which boys attain maximum growth during the adolescent spurt, age at peak height velocity (PHV). Some boys may reach PHV at 12 years (early maturing), while others may not attain it until 15 years of age (late maturing). In addition to variation in ages of attainment, there are problems associated with the assessment of sexual maturity (largely cultural) and age at PHV (requires longitudinal data that span 5-6 years).

Skeletal maturation, on the other hand, can be assessed during childhood through adolescence. Skeletal maturation is monitored with x-rays (with low level radiation exposure) of the hand and wrist. Assessments provide an estimate of **bone or skeletal age**, the chronological age at which a specific level of skeletal maturity was attained by the reference sample upon which the method of assessment was based. A boy with a chronological age (CA) of 15.4 years has a skeletal age (SA) of 16.3 years; this means his bone age is equivalent to that of a 16.3 year old boy in the reference sample.

How is Bone Age Estimated?

Assessment of skeletal maturation is based upon changes in the skeleton which can be easily viewed on standardized radiographs, traditionally of the left hand and wrist. The hand-wrist is placed flat on the x-ray plate palm down with the fingers slightly apart. The changes which each bone goes through from initial ossification to adult morphology are fairly uniform. The specific features of individual bones which can be noted on a hand-wrist x-ray occur regularly and in a definite, irreversible order provide a record of skeletal maturation.

There are three commonly used methods for estimating bone age: the Greulich-Pyle, Tanner-Whitehouse, and Fels methods. The methods are similar in principle - the hand-wrist radiograph of an individual is matched to a set of criteria; the criteria and procedures for deriving a skeletal or bone age differ among methods. Details of the methods are beyond this discussion; several features related to skeletal age are highlighted below.

The Greulich-Pyle (GP) method was based on a small sample of American children from the Cleveland (Ohio) area born between 1917 and 1942, thus representing the grandparents and great-grandparents of present children. With the Greulich-Pyle method, skeletal age should be based on the median of the skeletal ages assigned to each individual bone of the hand-wrist (there are 29 bones). In practice, however, a skeletal age according to the Greulich-Pyle method is generally, but improperly, based on the skeletal age of the standard plate to which the film of a child most closely matches (thus excluding variation among bones of the hand-wrist). Based on the account of the Asian Youth U-16 competition, it is likely that the latter approach was used.

The Tanner-Whitehouse (TW) method was based on British children from an orphanage and public schools. Most were born between 1940 and 1955. The method has gone through two major revisions. The most recent version (TW 3) has several different features. It only provides for maturity scores and in turn skeletal ages based on separate assessments of the long bones (radius, ulna, and metacarpals and phalange of the first, third and fifth digits, 13 bones) and round bones (7 carpal bones). The earlier versions provided for a 20 bone skeletal age based on the 13 long and 7 round bones. The reference values of TW 3 are based on samples of European (British, Belgian, Italian, Spanish), Argentine, Japanese and well-off American youth from the Houston (Texas) area. The age at attainment of skeletal maturity for the radius, ulna and short bones was lowered to 16.5 years in boys and 15.0 years in girls (it was 18.2 years and 16.0, respectively, in the TW 2 version).

The Fels method was based on middle class American children from south-central Ohio who were participants in the Fels Longitudinal Sample. The method uses different bones depending on the age and sex of the child, and provides a skeletal age with an associated standard error, which provides an estimate of the error inherent in an assessment. The latter is a unique feature which is not available with the other methods. The computation procedure for determining skeletal age in the Fels method weights the contributions of specific indicators depending on age and sex of the child.

The three methods yield a skeletal age or bone age. Given the differences in methods and reference samples, skeletal age of the same child derived with the Greulich-

Pyle, Tanner-Whitehouse and Fels methods are not equivalent; indeed, the resulting skeletal ages can be quite different.

Skeletal age or bone age assessment is basically a method to estimate the level of maturity which a child has attained at a given point in time. Skeletal age is expressed relative to chronological age. It is most often compared to chronological age, e.g., a boy's chronological age is 14.5 years while his skeletal age is 15.8 years). In this instance, the youngster has attained the skeletal maturity equivalent to that of a boy 15.8 years. Alternatively, a boy's chronological age may be 14.5 years but his skeletal age is 13.0 years. In this instance, the boy has attained the skeletal maturity equivalent to that of a boy 13.0 years of age.

Application to Youth Football Players

A wide of variation in skeletal age is evident among youth football players 10-12 years of age. There are approximately equal numbers of boys who are late (skeletal age lags behind chronological age by more than one year), on time (average, skeletal age is within plus or minus one year of chronological age) and early (skeletal age is in advance of chronological age by more than one year). As puberty and the adolescent growth spurt progress, the distribution of youth players by maturity status changes. Fewer late maturing and more early maturing boys are represented among youth players 13-14 years of age. After 14 years of age, there is a negligible number of late maturing boys, while the number of early maturing boys increases markedly. The evidence suggests that football systematically eliminates later maturing boys. By inference, a sample of 15-17 year old youth football players would include primarily average and early maturing boys, and some of the boys would be skeletally mature, i.e., adult. The issue of skeletal maturity of the hand-wrist, however, varies with the method of assessment. The examples in Tables 1 and 2 illustrate this point. Clearly, many adolescent football players are approaching skeletal maturity or are already skeletally mature. If bone age or another method such as MRI is used to evaluate passport age in U-16 or U-17 competitions, many players may be classified as older than they are in reality. They are early maturing boys (i.e., skeletal maturation is in advance of their chronological age) and would be classified erroneously on the basis of bone age as older than they are.

In epidemiology, this is labeled a **false negative** – the bone age indicates negative status (player is older than his passport age) when in fact the true status is positive (his passport age is correct, but his bone age is advanced). On the other hand, there is also the possibility that a late maturing boy who is chronologically older than the cut-off age would also be erroneously classified on the basis of bone age as younger than he is. This is labeled a **false positive** – the bone age indicates positive status (player's passport age is correct) when in fact the true status is negative (player is older than his passport age but his bone age is delayed).

Youth Athletes in Other Sports

Adolescent athletes in most sports available to boys tend to be, on the average, on time or advanced in biological maturity status – baseball, American football, basketball, ice hockey, track and field athletics (except distance runners), swimming. The situation for youth ice hockey players is quite similar to that for football. Approximately equal numbers of late, on time and early maturing boys are represented among youth players 12 years of age. However, at older ages, the majority of hockey players are advanced in skeletal maturity and many are already skeletally mature (Table 3).

Among 47 nationally select male Belgian track and field athletes 15.2 -18.3 years of age, 29 (62%) were skeletally mature (Tanner-Whitehouse 2 method). All except one 15 and 16 year old track and field athletes had a level of skeletal maturity which was in advance of that expected for his chronological age, while two-thirds (66%) of 17 and 18 year old athletes had a level of skeletal maturity that exceeded or equaled that expected for their respective chronological age.

Ethnic Variation

Biological maturation also varies among ethnic groups. Southern European youth tend to mature, on average, in advance of northwest European youth. Among American youth, puberty occurs earlier in Blacks compared to Whites. Maturity status is advanced in Japanese compared to American and British youth, and also advanced in samples of middle and upper class Latin American youth. Advanced maturity status in talented young athletes from different ethnic groups may thus reflect both ethnicity and selective factors within a sport. Among 33 Japanese male junior track and field athletes, 12.9-15.4 years of age, 20 (60%) were skeletally mature (Tanner-Whitehouse 2 method); the 13 remaining athletes were advanced in skeletal age by 1.6±1.1 years compared to their chronological age, 14.6±0.8 years. Similar results are apparent in Chinese and Japanese junior track and field athletes 13-17 years of age. Within each event, the athletes were advanced in skeletal age compared to chronological age and many 15, 16 and 17 year old athletes were skeletally mature (Tanner-Whitehouse 2 method).

Radius and Ulna

Among the 29 bones in the hand and wrist, the distal epiphyses of the ulna and radius are the last to attain maturity. As such, any method that attempts to assess the bone age of late adolescent youth will rely heavily on the stage of maturity of these two bones, in particular the radius. Trends based on two radiographic studies suggest the following. Among Denver boys, the modal ages (mode is the value that occurs most frequently in a distribution of scores) of epiphyseal union (fusion) of the distal epiphyses of the ulna and radius with their respective diaphyses (shaft) are 17.8 and 18.0 years. The average (± standard deviation) ages at epiphyseal union in Boston boys are 17.1±0.8 and 17.3±0.7 years for the distal ulna and radius, respectively.

Variability around these central tendencies merits attention in the context of using epiphyseal union to verify passport ages in age group competitions. It is relevant to the issue of false negatives and false positives discussed earlier. In a study of the skeletal remains of individuals of known age at the time of death (Korean War casualties), 55 individuals were 17-18 years and 52 were 19 years of age (based on military records). The authors graded the degree of union of the epiphyses of the distal ulna and radius. **The bones themselves were evaluated and not radiographs**. Results are summarized in Table 4. The variability of epiphyseal union - based on direct observation of the actual bones - should be noted. Union had not begun in 22% of the radii and 29% of the ulnae, but was complete in 35% of the ulnae and 29% of the radii of 17-18 year old males.

What is the relevance of this study of epiphyseal union to youth football players? Simply stated, both ends of the maturity spectrum are apparent – the mature and the immature – in a sample of 17 and 18 year old males. Many 17-18 year old males are already skeletally mature, i.e., biologically adult. They would be false negatives, i.e., the epiphyses suggest that they are older than they actually are. On the other hand, many 17-18 year old males are still skeletally immature, i.e., the final stage of skeletal maturation

– epiphyseal union – has not yet begun. They would be false positives, i.e., the epiphyses suggest that they are younger than they actually are.

Take Home Message

- The use of bone age to verify passport or chronological age has major limitations.
- Variation in the final stages of skeletal maturation of the hand and wrist is considerable.
- Given presently available information on the SA of youth football players, there is a likelihood of a relatively large number of **false negatives** – a bone age which indicates negative status (i.e., a player is older than his passport age) when in fact his true status is positive (i.e., his passport age is correct, but his bone age is advanced).
- There is also the possibility of **false positives** – a bone age which indicates positive status (i.e., a player's passport age is correct) when in fact his true status is negative (i.e., the player is older than his passport age but his bone age is younger).
- How can ages of players be verified? This is no foolproof method. Normal variation in skeletal (and sexual) maturation among adolescents is considerable. **The honesty of parents, players, trainers, administrators and others associated with the sport is probably the only method!**

Further Reading

Malina RM. Growth and maturity status of young football (football) players. In Science and Football, 2nd edition, edited by T Reilly and M Williams, London: Routledge, 2003, pp 287-306.

Malina RM, Bouchard C, Bar-Or O. Growth, Maturation, and Physical Activity, 2nd edition. Champaign, IL: Human Kinetics, 2004.

Sources of Data Cited in the Text

Hand-wrist radiograph of youth football players were provided by Dr. Luis Horta, Dr. Manuel Chamorro, Dr. Luis Serratosa and Dr. Francisco Morate. Greulich-Pyle skeletal ages were assessed by Dr. J. Rodrigues, while Tanner Whitehouse 3 and Fels skeletal ages were assessed by the author.

Data for ice hockey players were provided by Dr. G. Lariviere (see Lariviere G, LaFond A. Physical maturity in young elite ice hockey players. Canadian Journal of Applied Sport Sciences 1986; 11: 24p, abstract).

Data for track and field athletes are from Malina RM. Growth and maturation of child and adolescent track and field athletes. Final report to the International Athletic Foundation, Monaco, 2004.

Data on fusion of the distal epiphyses of the radius and ulna are from Krogman WM. The Human Skeleton in Forensic Medicine. CC Thomas: Springfield, IL, 1962, and Roche AF, Malina RM. Manual of Physical Status and Performance in Childhood, Volume 1b. New York, Plenum, 1983.

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Table 1. Skeletal maturity status among 14 elite Spanish youth players, 15.04-16.07 years of age.

- 2 were skeletally mature with the Fels method (15.7, 15.9 years),
- 11 were skeletally mature with the Tanner-Whitehouse 3 method (15.0-16.1 years), and
- 9 players who were skeletally mature with Tanner-Whitehouse 3 method but not with the Fels method had a chronological age of 15.71±0.34 years and a Fels skeletal age of 17.75±0.14 years.

Table 2. Skeletal maturity status among Portuguese youth players 15 – 17 years of age.

- 38 players 15.04 – 15.99 yrs, 6 (16%) had Greulich-Pyle skeletal age ≥18.0 years; 2 (5%) were mature with the Fels method,
- 30 players 16.03 – 16.98 yr, 18 (60%) had Greulich-Pyle skeletal age ≥18.0 years; 6 (20%) were mature with the Fels method, and
- 15 players 17.25 – 17.94 years, 11 (73%) had Greulich-Pyle skeletal age ≥18.0 years; 6 (40%) were mature with the Fels method.[1]

[1]The Greulich-Pyle method extends to 19.0 years, but differences between the plates at 18.0 and 19.0 years are negligible.

Table 3. Distribution of the maturity status of 85 youth ice hockey players with a mean age of 15.7±0.6 years.[1]

▪ late maturers	none
▪ on time (average)	32
▪ early maturers	31
▪ skeletally mature	22

[1]Tanner-Whitehouse 2 skeletal ages, based on Lariviere and Lafond (1986).

Table 4. Stages of union of the distal epiphyses of the ulna and radius in 17-18 and 19 year old males.[1]

	Ulna		Radius	
Degree of Union	17-18 yrs	19 yrs	17-18 yrs	19 yes
non-union	29%	7%	22%	7%
¼ united	1	-	3	-
½ united	11	5	14	5
¾ united	24	32	32	48
complete union	35	56	29	40

[1]Based on data reported in T.W. McKern and T.D. Stewart (1957): Skeletal age changes in young American males, analyzed from the standpoint of identification. Natick, MA: U.S. Army, Quartermasters Research and Development Command, Technical Report EP-45.