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Examination of ossification of the distal radial epiphysis using magnetic resonance imaging. New insights for age estimation in young footballers in FIFA tournaments

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ABSTRACT

Alongside a variety of clinical and forensic issues, age determination in living persons also plays a decisive role in the field of professional sport. Only methods of determining skeletal age which do not expose individuals to ionizing radiation are suitable for this purpose. The present study examines whether MRI diagnosis of the distal radial epiphysis can be utilised to monitor internationally relevant age limits in professional football.

The wrist area of 152 male footballers aged 18 to 22 years belonging to regional clubs was prospectively examined using MRI. The ossification stage of the distal radial epiphysis was subsequently determined on the basis of established criteria used in determining the maturity of the medial clavicular epiphysis.

For the first time, we ascertained evidence of an increase in the prevalence of the phenomenon of threefold linear stratification (hypointense line, hyperintense line, and hypointense line) in the representation of the fused epiphyseal plate of the radius using magnetic resonance imaging with increasing chronological age. Within our study population, test persons with an ossified epiphyseal plate without any verifiable epiphyseal scar were not represented. The presumably high minimum age of entry into this final stage of development (>22 years) must be verified in the course of further studies.

According to the results of the present study, the fused epiphyseal plate of the distal radius provides potential maturation criteria which appear suitable for reliable monitoring of all relevant age limits in international football with the aid of magnetic resonance imaging.

1. Introduction

Over the past 20 years, scientific insights gained in the field of age diagnosis in living persons have been mainly inspired in an almost unprecedented manner by the specific requirements of practical forensic work [1–6]. However, application of the results of this development is not restricted to conventional medical and legal contexts. Thus, the methods used to clarify the stated age of living individuals are also gaining increasing significance in the organisation of elite sporting competitions [7]. In this context, it is the primary responsibility of international sporting federations to guarantee by means of age divisions that all participants enjoy the equal opportunities required for ethical reasons. At the same time, any physical and/or psychological and social strain on sportspeople not in line with their age is to be avoided as a significant source of self-endangerment in relation to health. Finally, with regard to contact and collision sports, in particular, it is also important to protect physically weaker team members from injuries caused by older players.

Tournaments organised by the *Fédération Internationale de Football Association* (FIFA) as an international football governing body include the U-17 and U-20 World Cups. These are both staged between the best junior male national teams in uneven years and the best junior female national teams in even years. In these competitions, all male and female footballers are entitled to play if they reach the relevant age limits on 1 January of the year of the Cup Final at the earliest. More specifically, therefore, participation following completion of the 18th or 21st year of life, respectively, is excluded. The age range between 15 and 23 years in both sexes is highly relevant to international youth football for the various championship tournaments organised by the continental federations subordinate to FIFA.

The identity of all participants is monitored by the organisers in the run-up to each football tournament on the basis of personal documents, such as ID cards, passports, birth certificates, etc. On a number of occasions in the past, suspicions have arisen that the age stated for individual junior players was incorrectly low [7–9]. A certain proportion of

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cases may be due to delayed, sometimes unsupported, in some places even completely lacking, registration of births, such as is the case especially in various countries of origin for geographic and cultural reasons. However, cases of criminally motivated misdeclarations in the sense of so-called "age doping" can also scarcely be ignored. By this means, the chances of an individual player to be signed by a renowned football club may possibly be increased [10]. In general, however, the illicit participation of older players also wrongfully enhances the prospects of a team victory in age-restricted football tournaments.

In recent times, questions relative to the general meaningfulness and the ideal means of monitoring age in professional youth football have repeatedly been the subject of scientific debate [11,12]. In view of the fact that the genetically determined maturation sequences of individual osseous elements occur within a certain range of variation with a comparatively high level of regularity [13–16], skeletal maturation can still be considered the most significant indicator of biological age. However, the X-ray examinations required for the majority of established methods of determining skeletal age are not legally justified in the field of sport, and in the judgment of the International Olympic Committee (IOC), cannot be advocated according to sports ethics [7]. For this reason, future research efforts in this area must be mainly focussed on further establishing examination methods for purposes of skeletal age diagnosis which do not expose the individual to ionizing radiation.

So far, a number of general approaches to resolving this problem have been highlighted [17–25,25a,25b,25c]. Initial trendsetting attempts have been undertaken to routinely apply such methods using magnetic resonance imaging to ascertain the ossification stage of the distal radial epiphysis to determine the age of professional footballers [9].

The objective of the present pilot study is to examine whether MRI diagnosis of the distal radial epiphysis can be utilised to monitor internationally relevant age limits in professional football.

2. Test persons and methods

The tests encompassed the prospective evaluation of magnetic resonance imaging scans of the area of the left wrist in a total of 152 German male volunteers aged between 18 and 22 years. All details of age were monitored on the basis of a tendered official identification document. The 18-, 19-, and 21-year-old age groups each comprised 30 persons, the 20- and 22-year-old age groups 31 persons.

The study population was comprised of amateur footballers who were enrolled at the time of the study as active players in a club registered with the German Football Federation. Growth disorders were ruled out when collecting the medical history of the test persons.

All the MRI examinations on which the study is based were performed in the months from February to June 2011 at the Institute of Clinical Radiology of the University Hospital Münster (Germany). The project was supported by a positive vote of the ethics commission responsible; this vote was based on a comprehensive explanation of risks and the written declaration of consent given by all test persons.

The imaging diagnostics were performed on a 3.0 T scanner (Achieva, Philips Medical Systems, Netherlands) using a surface coil (Sense Flex M, Philips Medical Systems, Netherlands). Based on clinical radiological methods of hand age diagnosis, a T1-weighted turbo spin echo (T1-TSE) sequence in coronal sectional orientation (TR: 635 ms; TE: 11 ms; FA: 90°; NSA: 3; FoV: 100 × 100 mm; slice thickness: 1.5 mm; scan time: 6.0 min; measured matrix: 248 × 180 [m × p]; measured voxel size: 0.4 × 0.5 × 1.5 mm; recon voxel size: 0.2 × 0.19 × 1.5 mm) was used for image acquisition so as to achieve a scan of as long a section of the distal radial epiphysis as possible. Only scans of the left hand were included in the investigation, as significant traumatic changes to the right hand are more prevalent in the population as a whole. Potential differences between the sides in the degree of maturation do not represent a relevant source of error in determining the age of the hand skeleton [25d].

A ViewForum Workstation (Philips Medical Systems, Netherlands) with a diagnostic monitor was available for masked assessment of the MR scans. To determine the ossification stage of the distal radial epiphysis, a combination of the classification systems proposed by Schmeling et al. [26] and by Kellinghaus et al. [27] was used (Table 1). When determining the ossification stage, the entire image sequence generated for each test person was evaluated. When determining stages 2 and 3 (including substages), the slice with the most advanced degree of ossification was selected in each case. Stage 4 was determined whenever the growth plate was fully ossified in all the slices and an epiphyseal scar or the remains of one were visible in at least one slice. Stage 5 was determined whenever the growth plate was fully ossified in all the slices and no traces of any epiphyseal scar were visible in any of the slices.

All the images were first evaluated by an examiner (forensic physician) with experience in skeletal age determination. This first examiner evaluated 30 cases for a second time after a time lapse of three months. In the case of this partial group, a further evaluation was performed by a second examiner (forensic physician) who also had wide experience in skeletal age determination. All evaluations were performed without knowledge of the age and sex of the individuals examined.

We used SPSS 16.0.1 (IBM SPSS Statistics) software for the statistical evaluation of the data. A variety of statistical measures (minimum age, maximum age, mean value with standard deviation, and median with lower and upper quartiles) were calculated to describe the individual ossification stages. The kappa coefficients were calculated to determine intra- and interobserver agreement.

3. Results

Figs. 1 to 5 illustrate the characteristic MRI findings of ossification stages IIc, IIIa, IIIb, IIIc, and IV of the distal radial epiphysis which were detected in the study population. Ossification stages I, IIa, IIb, and V were not found amongst our test persons.

In all cases included in the study, it was possible to determine the ossification stage of the distal radial epiphysis using magnetic resonance imaging. For intraobserver agreement, a kappa coefficient of 0.94 was calculated. According to the verbal ratings proposed by Altman [28], this corresponds to a very good level of agreement. For interobserver agreement, a kappa coefficient of 0.88 was calculated. This value also corresponds to a very good level of agreement.

Ossification stages IIc and IIIa were established exclusively in the 18-year-old age group, whilst ossification stage IIIb was found only in the 18- and 19-year-old age groups. Within the studied age spectrum as a whole, ossification stage IIIc was ascertained with decreasing frequency as chronological age increased, whilst ossification stage IV became increasingly frequent.

Table 1
Stage classification of ossification of the distal radial epiphysis modified according to Schmeling et al. [26] and Kellinghaus et al. [27].

Stage	Description
I	The epiphysis has not yet ossified
IIa	The length of the ossified epiphysis is one-third or less compared to the width of the metaphyseal ending
IIb	The length of the ossified epiphysis is between one-third and two-thirds compared to the width of the metaphyseal ending
IIc	The length of the ossified epiphysis is over two-thirds compared to the width of the metaphyseal ending
IIIa	Epiphyseal–metaphyseal fusion completes one-third or less of the epiphyseal plate
IIIb	Epiphyseal–metaphyseal fusion completes between one-third and two-thirds of the epiphyseal plate
IIIc	Epiphyseal–metaphyseal fusion completes over two-thirds of the epiphyseal plate
IV	The epiphyseal plate is fully ossified and the epiphyseal scar is visible
V	The epiphyseal plate is fully ossified and the epiphyseal scar is no longer visible