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ORIGINAL ARTICLE

Comparison of MR images for age determination; T1 weighted images (T1WI) versus T2* weighted images (T2*WI)

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Abstract

***Purpose*: T1WI (T1 weighted image) was acquired in order to grade bone fusion following the studies by FIFA (Federation Internationale de Football Associations). Research using images other than T1WI has not been reported. The aim of this study is to evaluate the grade of epiphyseal fusion by T2* weighted images (T2*WI) and to investigate new findings on T2*WI as compared with T1WI.**

***Methods*: A total of 87 subjects, all junior football players between the ages of 12 and 17 years old, were examined. T1 and T2* WI were obtained using a 1.2T Open type MR system. The T1WI and T2*WI were rated twice randomly by four radiologists using the FIFA grading system.**

***Results*: The intra-rater reliability for grading was higher in T1WI (The Intraclass Correlation Coefficient (ICC)=0.949-0.985) than in T2*WI (ICC=0.917-0.943). The inter-rater reliability for grading was also higher in T1WI (ICC=0.923) than in T2*WI (ICC=0.867).**

***Conclusions*: This research showed that T1WI is a better sequence than T2*WI to evaluate bone fusion following FIFA protocol. It was speculated that the reason for this is that T1WI has higher tissue contrast resolution and enables clearer images of the epiphyseal fusion than T2*WI and the grading system by T1WI was not suitable for T2*WI.**

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INTRODUCTION

There are approximately 240 million football players all over the world. We can say that it is one of the most popular sports in the world. It has been greatly influential and has helped young people to build healthy minds and bodies. Therefore, many international football championships organized according to age have been held, including the FIFA U17 (under 17 years old) World Cup and the AFC (Asian football confederation) U16 (under 16 years old) Championship. However, organizers of age-related tournaments sometimes face the problem of age-cheating, which may jeopardize the fairness of the competitions. There is no doubt that players after puberty perform better than players before puberty in both physical and mental aspects. By age 16 and 17 almost everyone has at least entered puberty. In fact, there were some cases in which some players were highly suspected of being overage [1].

X-rays of hands and wrists for age determination [2] have been adopted since early days in some sports organizations. However, it is not considered ideal to expose healthy young players to radiation for age determination.

Dvorak et al. suggested age determination with MRI as a method without radiation exposure [3]. Only T1 Weighted images (T1WI) were used for age

determination, but T1WI are not always able to clearly describe the existence of the remaining unfused area of the radial epiphysis. This judgment is very important to determine if the players are less than 17 years old or not in sports.

The aim of this study is to explore the possibility of T2* weighted images (T2*WI) as another sequence in addition to T1WI to determine the process of bone fusion of the radial epiphysis and explore new findings.

METHODS AND SUBJECTS

Subjects:

A total of 87 football players in JFA academy FUKUSHIMA living in a boarding house were examined; these included 58 males (12-16 years old, average age: 15.07 years) and 29 females (13-17 years old, average; 15.65 years). This study was approved by the ethical review board of the Japan Institute of Sports Sciences. Before the examination, all subjects were fully informed of the protocol as well as the purpose of this study, and provided their own and their guardian's informed consent to participate in the examination.

Methods:

A vertical magnetic field 1.2T Open MRI model (OASIS manufactured by HITACHI Medical Corporation) and a knee coil were used to obtain MR images. In order to keep reproducibility, an acrylic board which had the same width as that of the knee coil was placed in the center of the cylindrical knee coil parallel to the bed.

The subjects lied down supine in a comfortable position and positioned their palm on the board. Their left hand was compressed by a cushion and fixed on the board to avoid body motion (Fig.1). Then, their arm was positioned to align the middle finger and elbow in a straight line parallel to the bed. The right hand was scanned in players with past injury to their left hand.

Coronal Spin echo (SE) T1WI and Gradient echo (GE) T2*WI were obtained through pre-saturation on the wrist side.

Field of view (FOV) was determined to cover the area from the fingertips to the distal radius and ulna with the slices parallel to the acrylic board.

Parameters for T1WI were as follows : SE sequence, acquisition time; 4min48sec, repetition time(TR) msec/echo time(TE) msec; 500/12.6, Echo Train Length(ETL);1, number of phase/frequency encode (PP/FE); 512,512, Flip Angle(FA) ; 90deg, slice thickness; 3mm with 0.3mm spacing, acquisition matrix(Mx); 512*512, FOV; 22×22 cm.

The parameters for T2*WI were as follows: GE sequence, acquisition time; 5min48sec TR/TE=400/12, PP/FE; 512,512, FA 30deg, 3mm slice thickness

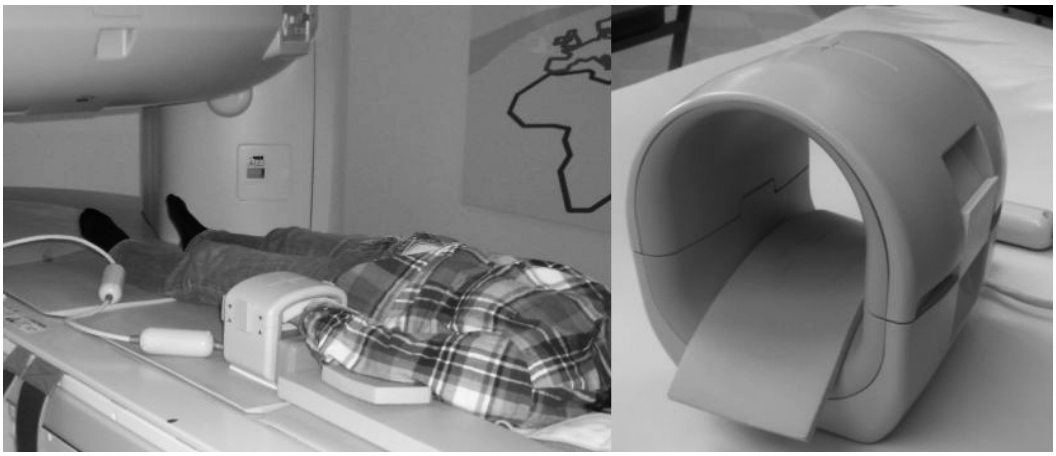

Fig 1: Position of subject in the gantry (left). The open MRI configuration allows subjects to be in a position of comfort and put the body part to be examined at the center of the magnetic field. Knee coil (right).

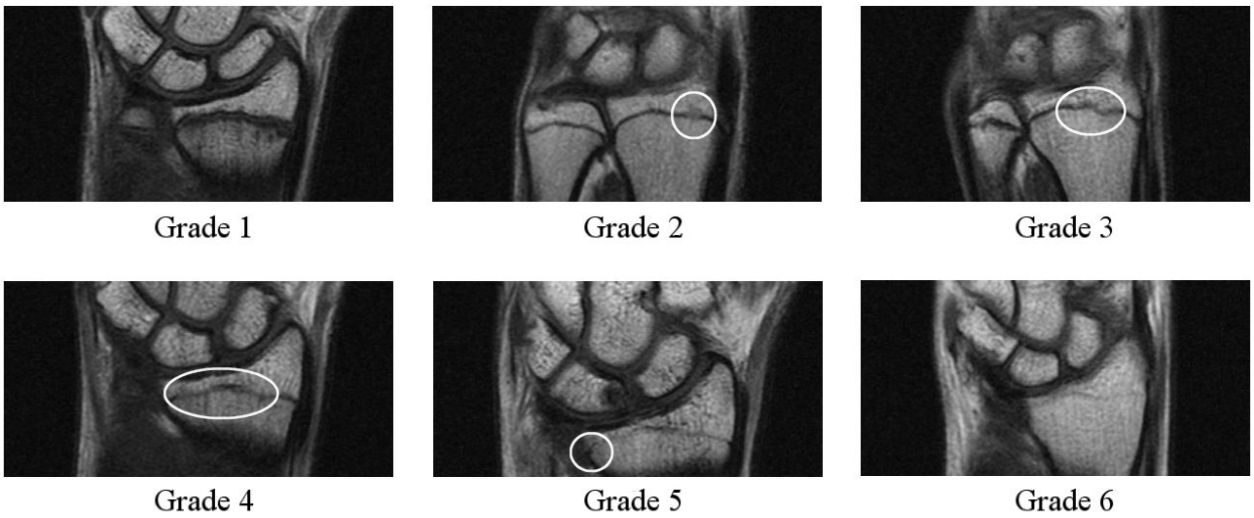

Fig 2: T1W images of wrist of each grade according to the FIFA grading system.
Grade 1 is a completely unfused epiphysis. Grade 2 is the fusion of the part that is enclosed by white lines. Grade 3 is 50% or less fused. Grade 4 is that the fusion proceeds, unfused epiphyses least 5mm (white circle). Grade 5 is less than 5mm in the incomplete fusion of the epiphysis (white circle). Grade 6 is completely fused epiphyseal line.

with 0.3mm spacing; Mx 512*512; FOV:22×22 cm.

Four radiologists graded both T1WI and T2*WI of all the players twice randomly using the FIFA grading system [3], which is based on the degree of bone fusion of the left radial epiphysis in T1WI. Example images are shown in Fig. 2.

- Grade 1: The radius epiphysis is completely separated and has no fusion.
- Grade 2: Early fusion: A part of the radius has fused.
- Grade 3: The fused part is less than 50% of the radius.
- Grade 4: The fused part is at least 50% of the radius, there is a healing part not more than 5mm.
- Grade 5: 5mm or less are not in the fused portion of the radius.
- Grade 6: The radial epiphysis is completely fused.

All data were processed on a Windows computer (Microsoft Corp, Redmond, Washington, USA). The statistical procedures were performed using R 2.8.1. The statistical method applied was Intraclass Correlation Coefficient (ICC). The ICC was used to determine statistically the intra-rater and the inter-rater reliability. This ICC is a general measurement of agreement or consensus, where the measurements used are assumed to be parametric (continuous and have a normal distribution). The Coefficient represents agreements between two or more raters or evaluation methods on the same set of subjects [4].

RESULTS

87 hands were scanned using T1WI and T2*WI. Eight MR images out of 174 images (4.6%) were affected by motion artifact. Figure 3 shows typical examples of T1WI and T2*WI.

Four raters each graded all 348 images. On T1WI, 3 cases were evaluated as Grade 6 by one or more raters and 1 case out of the 3 was evaluated as Grade 6 by all raters. On T2*WI, 11 cases were evaluated as Grade 6 by one or more raters and no cases out of the 11 were evaluated as Grade 6 by all the examiners.

Table1 shows differences in grading between T1WI and T2*WI.

Bone fusion tended to be considered more advanced and graded higher on T2*WI than T1WI. Lower and higher grading in T2*WI than in T1WI were found in 21 cases and in 115 cases, respectively.

Table 1: A differences of grading between T1WI and T2*WI

Examiner	A	B	C	D	Total
T1WI=T2*WI	57	68	35	52	212
T1WI>T2*WI	2	5	5	9	21
T1WI<T2*WI	28	14	47	26	115

Fifty eight cases out of the 115 were evaluated as Grade 1 on T1WI and Grade 2 on T2*WI, this was the most common tendency.

The analyses with ICC of intra-rater reliability and inter-rater reliability are shown in Table 2, respectively. The intra-rater reliability and inter-reliability for grading were higher in T1WI than in T2*WI.

Table 2: The results of intra-rater reliability analysis (ICC Model 1 and 2)

	Model 2				Model 1
Rater	**A**	**B**	**C**	**D**	
T1WI	0.985	0.951	0.949	0.976	0.923
T2*WI	0.943	0.917	0.933	0.933	0.867

DISCUSSION

To obtain the wrist images using a conventional high field closed MRI, the subjects are asked to lie down and remain still in a prone position keeping their arm stretched up for the duration of the examination. This position is not easy to keep and can induce motion artifact, which affects the quality of images, especially under the condition of long examination time in young subjects such as this study (acquisition times of T1 and T2*WI was 4min48sec and 5min48sec, respectively). On the other hand, an open MR machine allows subjects to lie down comfortably in the supine position with their arm placed down in a more natural position compared to the core-type MRI machine.

Therefore, less motion artifact appears on the images and their qualities are clear. In fact, the percentage of

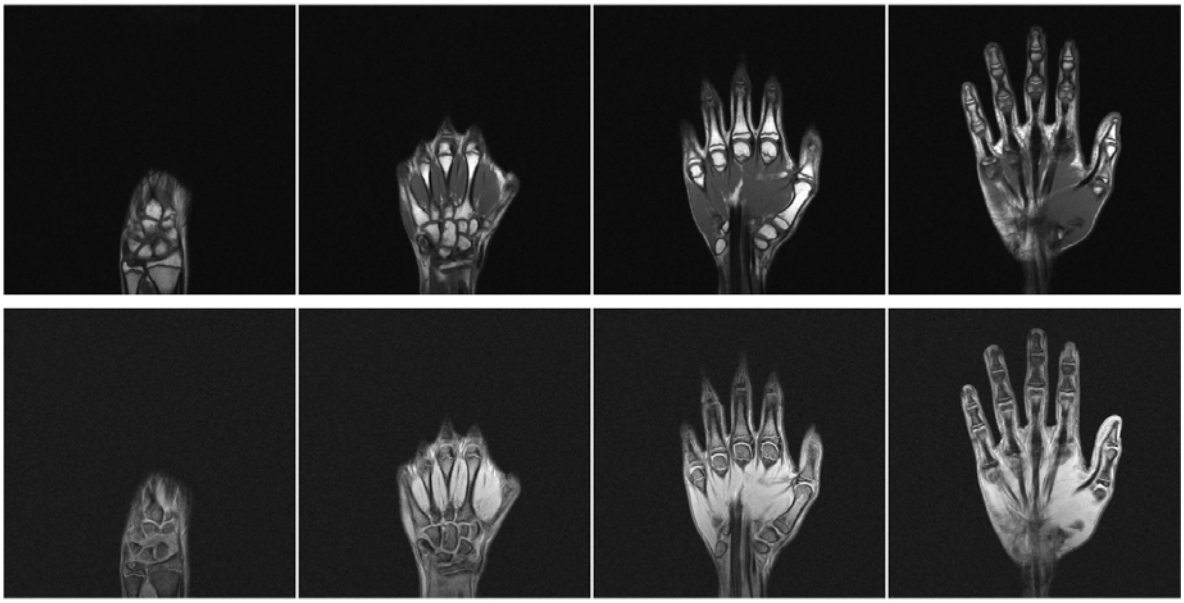

Fig. 3: Coronal MR images of hand & wrist. Upper row: T1WI. Lower row: T2*WI. The bone marrow is described as high and epiphysis as low in T1WI. Opposite signal pattern is showed in T2*WI.

the images affected by motion artifact remains at only 4.6% in this study, this may indicate that the open MR configuration enables subjects to be scanned in a more comfortable position than the closed configuration.

The reason why a knee coil was used in our study instead of a wrist coil was to obtain the images of the whole hand and wrist, which requires a wider FOV. Even if the knee coil receives a lower signal, the advantage of using open configuration is that it allows moving body parts, such as the wrist, away from the center of the body to the center of the magnet field so the quality of images with a knee coil are comparable to those with a wrist coil.

The reason why T2*WI is selected is because it can describe epiphyseal cartilage and bone marrow as a high signal and low signal, respectively; and this signal pattern by T2*WI is opposite to the one by T1WI. Therefore we thought that there was a possibility to detect new findings. T1WI showed high intra-rater and inter-rater reliability compared with T2*WI. In fact, the results showed that intra-rater and inter-rater reliabilities of T2*WI were lower and the variation was remarkable. Especially inconsistent were the evaluation results among examiners regarding Grade 6.

For evaluation of T2*WI, further investigations with increased sample numbers are required because bone fusion in most of the subjects in our research was not so advanced.

According to FIFA protocol using T1WI, Grade 6 is found in nearly all players over 17 years old and considered to be overage in U16 and 17 tournaments; therefore, differentiation between Grade 5 and 6 is very crucial and it is possible that raters are encountering difficulties grading the level of bone fusion. In this research, T2*WI had been expected to be another usable sequence that could help distinguish Grade 5 from 6 due to the different signal pattern of epiphysis to T1WI; however, unfortunately, new findings using T2*WI were not found.

We found that T2*WI is not ideal for grading bone fusion while T1WI is. Therefore, FIFA protocol prepared for grading by T1WI is unsuitable for grading by T2*WI. We speculated that T1WI is easier for grading because its tissue contrast between fatty bone marrow and grown cartilage is higher than T2*WI.

On the other hand, we found that, on T2*WI, patterns of epiphyseal lines which were graded 1 on T1WI can be classified into 4 groups (fig.4). Pattern A

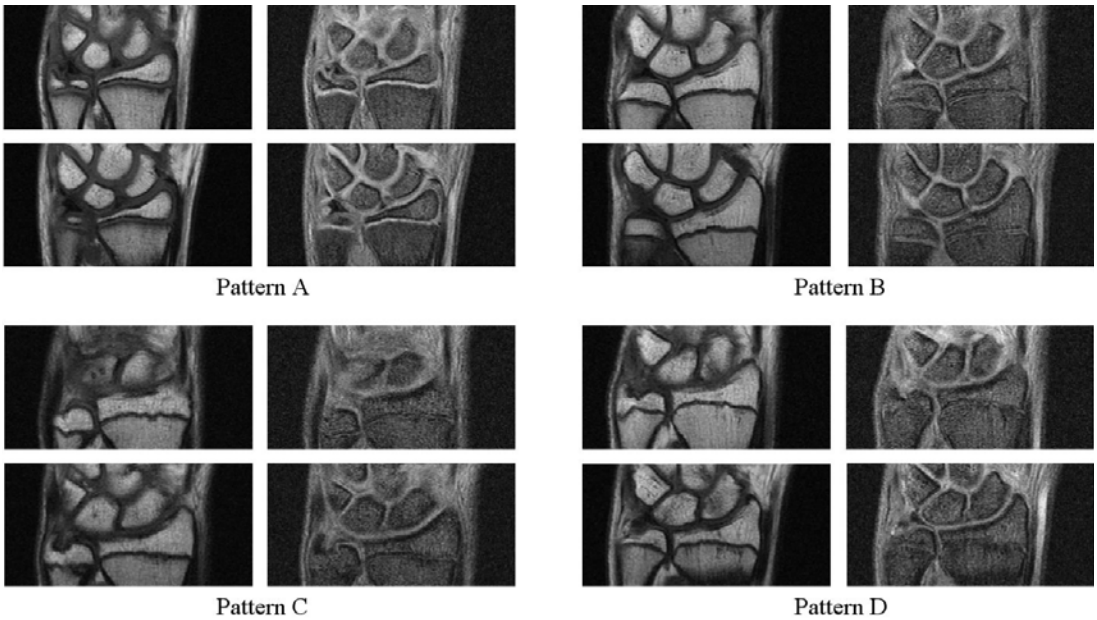

Fig. 4: T2*WI and T1WI are shown by two sheets each of four patterns. As for T1WI, the epiphyseal line is clearly described as the low signal band in all the images. Epiphyses were classified into the following patterns on T2*WI. Pattern A: white band-shaped clear epiphyseal lines. Pattern B: thin black lines in white band-shaped epiphyseal lines. Pattern C: thin white lines in epiphyseal lines. Pattern D: partially shows hypointensity in epiphyseal lines.

shows white band-shaped epiphyseal lines clearly. Pattern B shows thin black lines in white band-shaped epiphyseal lines. Pattern C shows thin white lines in epiphyseal lines. Pattern D partially shows hypointensity in epiphyseal lines, and thus, was given a higher grade on T2*WI.

With further research in the correlation between age and this classification, T2*WI may have potential to be useful in age determination in championships for players younger than 17 years old.

If a new grading system using the feature of T2*WI could be established, it may be useful to raise accuracy by combining its application with T1WI. However, at present, there are not many samples, and so proposing a new grading system is not appropriate. After this we need to increase the number of samples to improve the accuracy of bone age determination. We would like to investigate to clarify the relation between T2*WI and T1WI, and to examine whether a new grading system, which uses T2*WI independently or in combination with T1WI, can be advocated.

CONCLUSION

We did not find evidence to say that T2*WI is worthy of being introduced to age determination in this research. However, it provided a new insight that the patterns of epiphyseal lines of younger people can be classified into other age groups.

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Conflict of interests: None

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