Brief review

Muscle characteristics of Japanese scooer players using NMR

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1 Introduction

This is a brief review on the muscle characteristic of elite soccer players in Japan. The information about the muscle characteristic of elite soccer players seems abundant but is, as a matter of fact, quite scare. This is because muscles are concealed and, therefore, can hardly be seen directly. The field of sports sciences witnessed the initiation of muscle biopsy in 1960's, enabling us to obtain the direct information about the muscle cell. The muscle biopsy is, however, not a practice athletes like to undergo as it is accompanied by an incision. It may be further difficult to inspect in-season changes of a muscle. These are the reasons for source data on elite athletes, and it has remained unknown within a black box how the muscles of such athletes are characterized and what changes take place due to training.

2 NMR

We have studied the muscle characteristic of Japanese top ranked soccer players using the MR equipment (Fig.1). This equipment enabled us to obtain the information about elite athletes as it allows morphological and biochemical information about muscles to be obtained *in vivo* through the irradiation of a living body with magnetism. At first, it is discussed that NMR data on a topic of the morphological characteristic of Japanese top-ranking soccer players' muscles as well as of the relationship between in-season training and muscle characteristic. Figure 2 shows an axial image of thigh obtained from MRI. It covers the section from the knee to the upper part of thigh. The muscles, bones, and fats are clearly depicted.

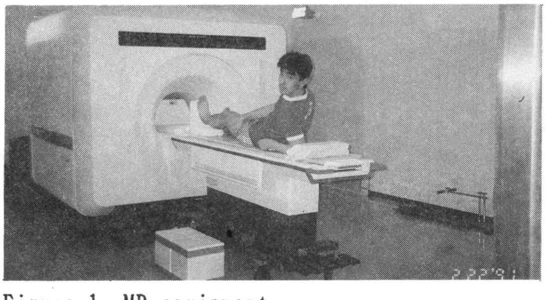


Figure 1 MR equipment.

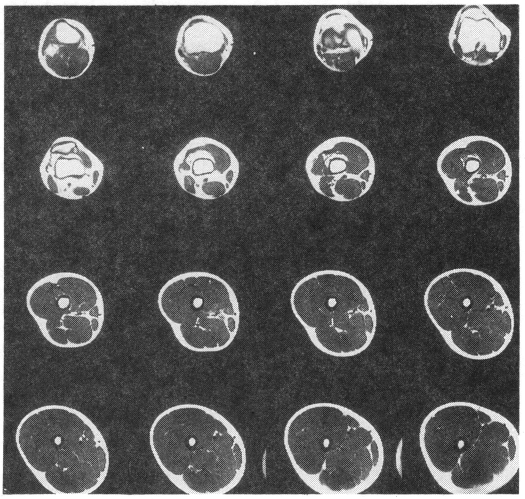


Figure 2 Axial image of thigh obtained from MRI.
It covers the section from knee side (top) to upper thigh (bottom).

Figure 3 shows a picture taken by a method called MRS to obtain muscle energy metabolic information. From left to right, inorganic phosphate, phosphocreatine, and ATP are shown. And, in this spectrum, the state at rest is shown up to the 4th streak from the bottom, that during exercise by the next 6, and the other of the streaks are recovery. When exercise is started, inorganic phosphate increases in its peak while phosphocreatine decreases. The use of ^{31}P MRS also permits us to determine an intracellular pH. Moreover, since the reduction in the intracellular pH has been found proportional to the amount of lactic acid accumulated within a muscle cell, ti can be inferred whether or not a glycolytic system has been mobilized if the value of intracellular pH is known.[3] Such information has so far been unable to be obtatined unless subjected to muscle biopsy.

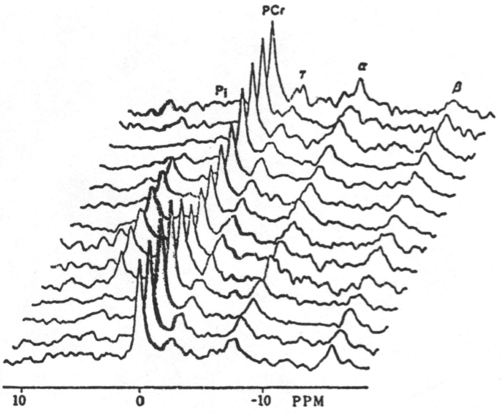


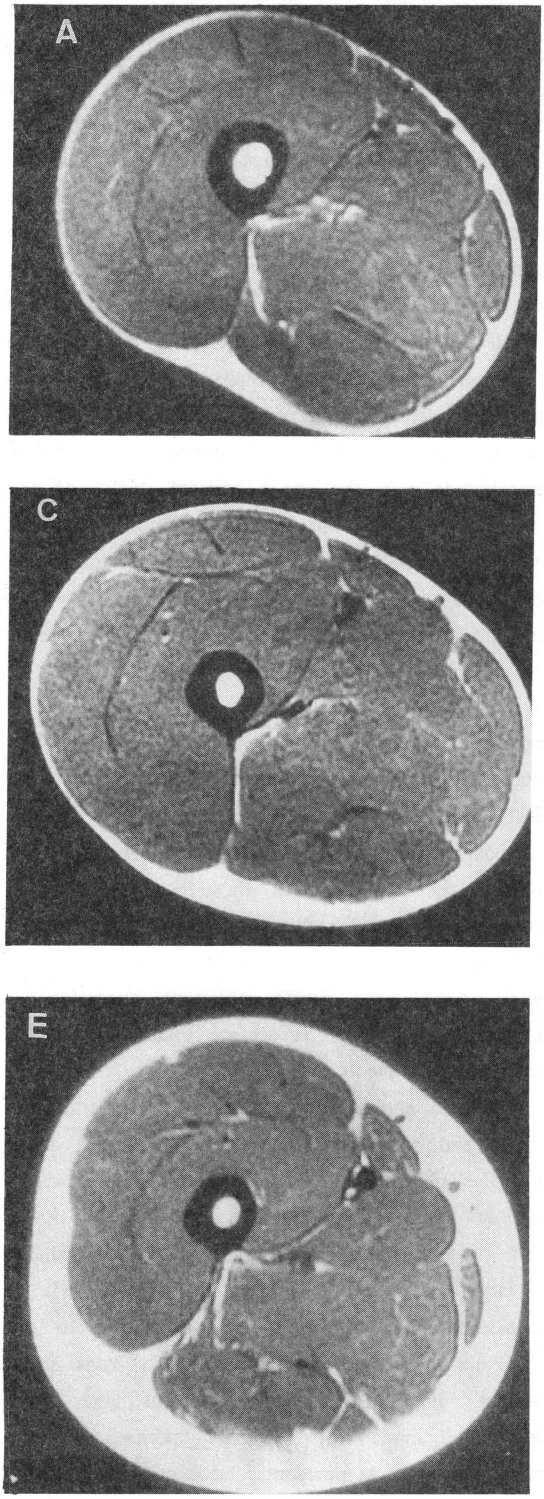
Figure 3 A series of ^{31}P MRS spectra *in vivo* at rest (lower 4 traces), during exercise (middle 6) and recovery (upper 4).[8)]
Pi, inorganic phosphate ; PCr, phosphocreatine ; α, β, γ, three phosphate groups of adenosine triphosphate (ATP)

3 Comparison between soccer players of muscle cross-sectional area andother sport's events

Figure 4-A is an axial image of the thigh depicted by MRI for a national soccer player as a member of the japanese delegation. The muscle quadriceps femoris and hamstring are among those well trained. Subcutaneous fat is also characteristically scarce. Figure 4-B shows that an MR imaging of a judo player who has won a world championship twice. It is particularly notable that the area of hamstring is larger than the soccer player's large one. That subject, though weighing 90 kg, has scarce subcutaneous fat, indicating a large composition ratio of muscles. Figure 4-C shows that the MR imaging of a male volleyball player of the Japan national team. This player has most characteristically, highly developed M. rectus femoris. It is generally well that M. rectus femoris plays an important role in jumping motion. This picture indicates that the development of this muscle is still ever important for volleyball players who repeat such a motion during a game. Figure 4-D shows an example of those players observed to have the highest developed muscles with very little subcutaneous fat among the elite athetes contained. He was an athletic pole jumper and had held a Japanese record until recently. Figure 4-E shows an untrained male's axial image. This subject, unlike an athlete, has characteristically less developed muscles and abundant subcutaneous fat. Figure 5 shows cross-sectional areas of various muscle groups calculated from each image of the thighsobtained by MRI.[4)] The topside of a picture corresponds with the upper part of thigh and the lower part covers the section around upper part of the knee. From left to right, each column gives the area of hamstring, M. vastus medialis and M. vastus intermedius combined, M. vastus lateralis, and M. rectus femoris, respectively.

This figure may, therefore, be considered as a morphological aspect of thigh muscles. They are, from left to right, the muscles of a track and field athlete, judoist, speed skater, soccer player, vollyball player and the untrained. A group of athletes used consisted of those who, represented each of all-Japan teams and who were ranked 10th or higher in each event in Japan. The above comparison clarifies different characteristics in the morphological aspect of thigh muscles for different sport events.

Figure 6 shows a comparison between a soccer player and sprinter. Quite characteristically, there is no significant difference observed in the cross-sectional area of upper-thigh, but in the lower part of thigh, the soccer player definitely exhibits a larger cross-sectional area of muscle. It is considered that this might be partly due to the fact that a coccer player not simply runs in a straight direction but also repeats the most important mode of kicking motion in his performance. At present, however, this cannot be explained to a full extent but is considered as an interesting fact. It also indicates the necessity



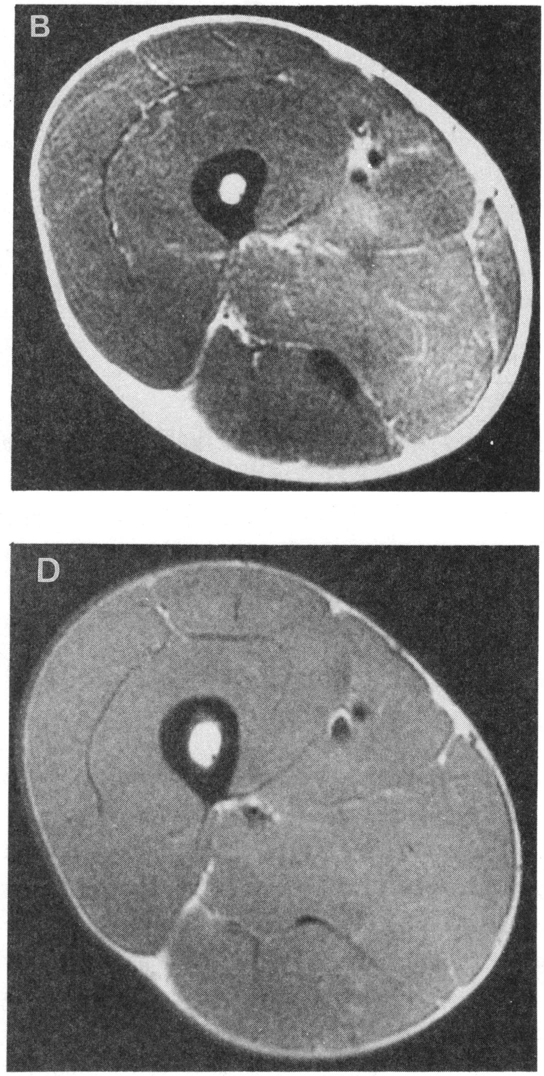


Figure 4 An elite athlete's image of thigh by MRI.[4] A, soccer ; B, judo;C, volleyball ; D, pole jumper E, untrained

to carry out such a training as applies load to all over the thigh when a soccer player executes strength training.

Figure 7 shows the area of muscle quadriceps femoris in its upper (70 %) and middle (50 %) and lower (30 %) parts of players in all Japan, Olympic team the 1st division of Japan Soccer League, respectively.[2] The All Japan exhibits a

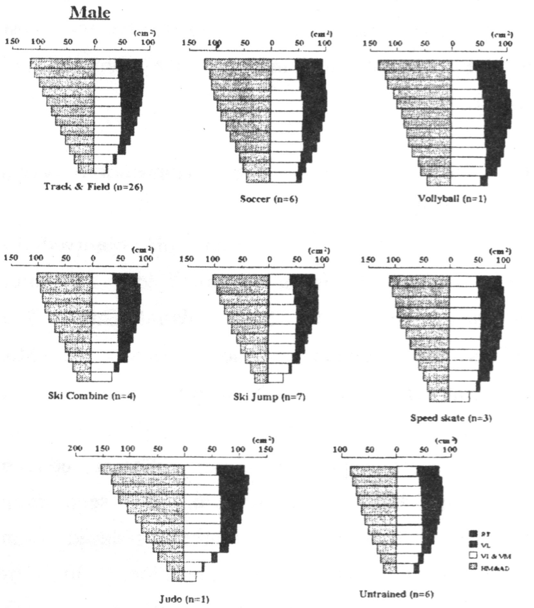


Figure 5 Cross-sectional areas of various muscle group calculated from each image of thigh obtained from MRI[4].

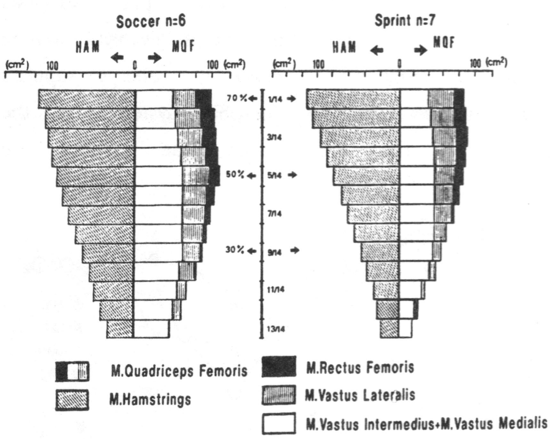


Figure 6 Comparison with soccer players and sprinters in cross-sectional areas of various muscle group[4].

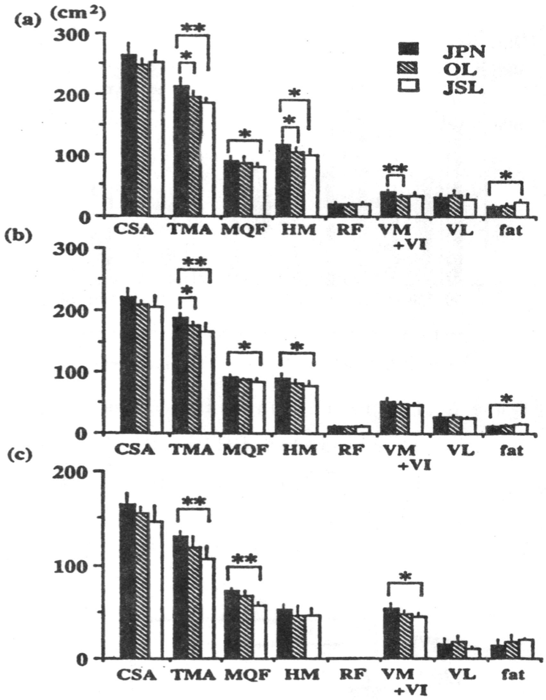


Figure 7 Muscle cross-sectional area of thigh in All Japan (JPN), Olympic and Youth (OL) and Japan soccer league (JSL) players.[2]
(a), upper thigh ; (b), middle thigh ; (c), lower thigh CSA, cross-sectional area; TMA, total muscle area ; MQF, quadriceps femoris ; HM, hamstring ; RF, rectus femoris ; VM, vastus mediaris ; VI, vastus intermedius ; VL, vastus lateralis

significantly higher value at every location and in both muscle groups than that of player from the Japan League players. This tendency is also observed in isokinetic strength, (Fig.8) and anaerobic power (Fig.9). In consequence, as a possible cause for the higher values in muscle strength and anaerobic power exhibited by an all Japan group, the greater of muscle mass may be cited. It is, therefore, be important to maintain a certain amount of muscles or more of it when

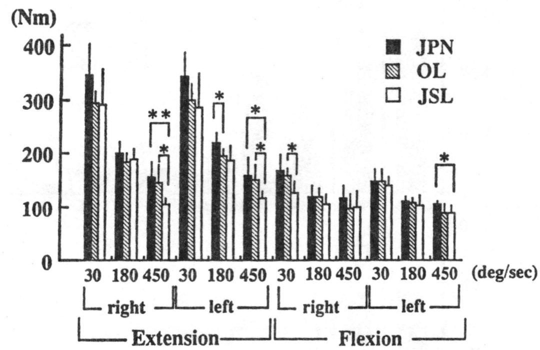


Figure 8 Leg extension and flexion torque in All Japan (JPN), Olympic and Youth (OL) and Japan soccer league (JSL) players[2].

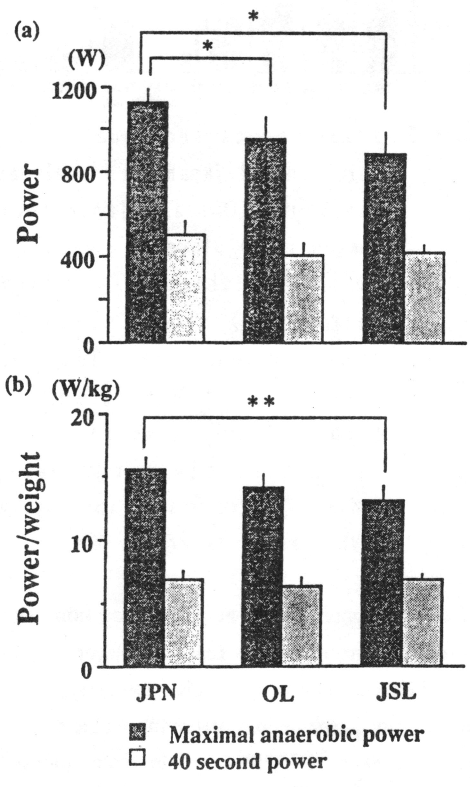


Figure 9 Maximal anaerobic power and 40 second power by bicycle exercise in All Japan (JPN), Olympic and Youth (OL) and Japan soccer league (JSL) players[2].

a soccer player is to be trained. Strength training among others is assumed to be the most effective method to increase the amount of muscles.

4 Muscle metabolism during competition period by MRS

Figure 10 shows in muscular pH observed by MRS from an all Japan players before and after the elimination for the Italian World Cup[6]. The subjects were kinetically loaded within the MR equipment and the muscle energy metabolism at that time was measured. The work rate of kinetic loading applied was not different beween before and after the elimination. As seen from this figure, the pH was scarcely reduced even during exercise before the elimination. In view of an ATP supply system, the energy for such exercise can be deemed to have completely been almost covered by the aerobic system. Nevertheless, despite the same exercise taken after the elimination, the pH dropped considerably. This means that a glycolytic system was also mobilized to cover the energy supplied in deficienct by the aerobic system for the exercise. For this reason, the muscles are

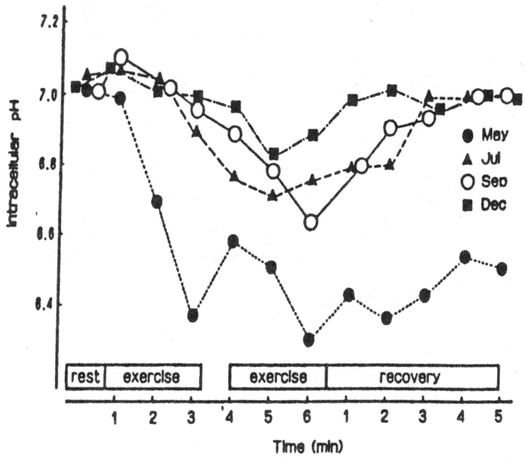


Figure 10 Changes in muscular pH observed from ^{31}P MRS in a Japan soccer league(JSL) player during a season[6].

supposed to be in quite a fatigued state at the time of measurement after the elimination. This trend held true of muscle strength, exemplified by a case of reduction by as much as 30 %.[6]

Figure 11 shows the state of changes in the muscular pH of a certain professional player when undergoing tha same test intermittently during a season.[9] The lowest value is shown by an off-season measurement and it seems understand able that the muscular condition depends largely upon the extent to which the muscles were trained. In the case exemplified previously, no strength or high-power training was given for about one-month period of the World-Cup elimination. What was responsible for the muscle fatigue after the competition may be due not only to the fatigue during the period of competition but also the absence of accompanying training. Because it has so far been found that the absence of such training for a month deteriorates the muscle capability considerably. It is, therefore, recommended that the strength training and high-power training showed be added to the physical training during middle or long-term competition seasons.

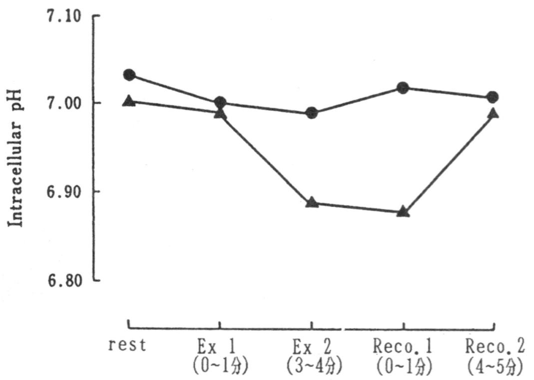


Figure 11 Changes in muscular pH observed form ^{31}P MRS in an all Japan soccer playerbefore and after the elimination for the Italian World Cup[6]. (● : pre, ▲ : post)

Conclusion

Figure 12 shows a certain player currently as a member of the Olympic team. The amount of muscles is smaller with considerable amount of fat. In fact, however, this is not a special case but rather observed in a large number of players in Japan. Most of them are the players belonging to the current J League. Therefore, this makes us feel that now is the time to fully reconsider the way of strength training and high-power training for Japanese soccer players.

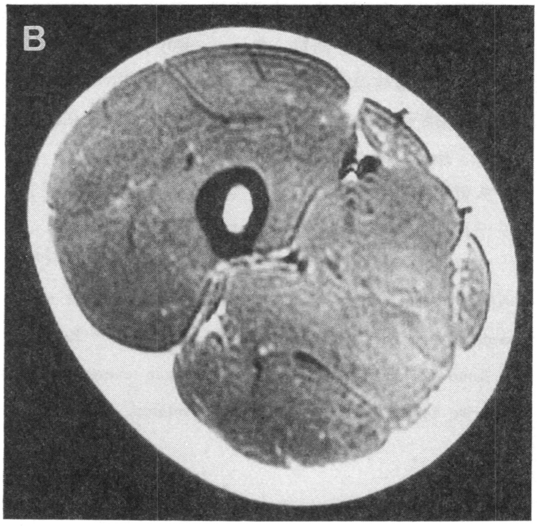


Figure 12 Axial image of thigh in elite soccer players[7].

This paper was presented at sports medicine seminar in 10th Asian Cup final championship 1992 at Hiroshima.

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