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AN INVESTIGATION OF THE RELATION BETWEEN THE 30 METER RUNNING TIME AND THE FEMORAL VOLUME FRACTION IN THE THIGH

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Abstract. Leg components are thought to be a related to speed. Only a limited number of studies have, however, examined the interaction between speed and bone size. In this study, we examined the relationship between the time taken by football players to run thirty meters and the fraction which the femur forms compared to the entire thigh region. Data collected from thirty male football players of average age 17.3 (between 16-19 years old) were analyzed. First we detected the thirty meter running times and then we estimated the volume fraction of the femur to the entire thigh region using stereological methods on magnetic resonance images. Our data showed that there was a highly negative relationship between the 30 meter running times and the volume fraction of the bone to the thigh region. Thus, 30 meter running time decreases as the fraction of the bone to the thigh region increases. In other words, speed increases as the fraction of bone volume increases. Our data indicate that selecting sportsman whose femoral volume fractions are high will provide a significant benefit to enhancing performance in those branches of sports which require speed. Moreover, we concluded that training which can increase the bone volume fraction should be practiced when an increase in speed is desired and that the changes in the fraction of thigh region components should be monitored during these trainings.

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Key words: Femur volume fraction - Speed - Magnetic resonance imaging - Stereology

Introduction

Anatomical and physiological profiles should be identified, firstly to enhance the performances of the sportsman as there is a close relationship between the

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structural and functional properties of the body. Thus, body components are the primary factors directly affecting the performance in all branches of sport. It is, therefore, crucial to have information on body components such as muscles, bone, fat and others in order to sustain personal and team success. An important biomotor ability required in sports is speed, or the capacity to travel or move quickly. The term speed incorporates three elements: reaction time, the frequency of movement per time unit, and speed of travel over a given distance. The relationship between these three elements sets the performance in an exercise requiring speed. Therefore the performance in the sprint depends on the reaction time, the stride length and frequency [6].

The most important factor setting the speed in running is the volume relationship between muscle, bone, fat and combining tissue components. The volume fraction of a component within a reference volume is a simple and very widely used parameter in biomedical science [14,19,20]. Thus it is used to express the proportion of a phase or component within the whole structure. The volume fraction of an X phase within a Y reference volume is simply expressed as follows:

$$V_V(X,Y) = \frac{\textit{Volume of X phase in Y reference space}}{\textit{Volume of Y reference space}} \quad (1)$$

where the $V_V(X,Y)$ indicates volume fraction of X phase within the Y reference volume. Using this approach, V_V (muscle, thigh), V_V (bone, thigh) and V_V (adipose tissue, thigh) i.e. the volume fraction of muscle, bone or adipose tissue within the thigh can be estimated. The volume fraction is a parameter that provides information about the volumetric interrelation of components within an examined organ or structure. Volume fraction ranges from 0 to 1 and is often expressed as a percentage [14].

The volume of the bones, which form the frame of the body is believed to have an effect on the performance of the individual. It is, therefore, worth examining whether or not there is an interaction between the volume of the bones and speed. There has, however, been no study in the literature which examines the relation between speed and the volume fractions of the structures forming the lower extremity.

In the present study, we examined the volume fraction relationship between the thigh components using a technique to estimate volume fractions, one of the modern stereological methods. We analyzed the relationship between the findings and the 30 meter running time and we further analyzed the interactions between the speed and the thigh components.

Materials and Methods

This study was conducted on a total of 30 young football players enrolled in the league of "Football Players who are Candidates of Professional Leagues". Their ages, heights and weights were registered. Height was measured with the anthropometric set and weight using a digital scale with a precision of 0.01. Thirty-meter running times of the subjects were recorded. Afterwards, the volume fraction of the femur within the thigh region was estimated using Magnetic Resonance Imaging (MRI).

Thirty-meter running time was measured on a grass field after the players had been requested to wear cleats. A cordless photocell device with a precision of 1/1000 was used to determine sprint times. Subjects were not accepted for the 30-meter-running session unless they had performed a proper warming-up consisting of 10-min at a comfortable jogging speed, typically 2.5 m/s. Subjects ran this distance twice with a 3-minute interval. The subjects' best results were recorded.

Using a 1.5 MR machine (Signa 1.5T SYS#GEMSOW, General Electronic, Wisconsin, USA), the MRI images of the subjects were obtained in two sessions lasting eight hours. After removing all their clothes except for their underpants, the subjects lay down on the table of the MRI device in a supine position. Scanning was performed using the following parameters: spin-echo axial, repetition time (TR): 3000, echo time (TE): 112/Ef, and field of view (FOV): 46×34cm. Each subject was scanned in horizontal plane with a slice-thickness of 1 cm and 3 cm intervals, i.e. the total slice thickness was 4 cm for all subjects. Using this sectioning parameter, a total of approximately 9 sections was obtained per subject.

In order to determine the lower and upper limits of the thigh on the MR images, the first section, where the thigh region was seen as a circle, was used for the upper part and the last section, where the lower part of the thigh was seen, for the lower part.

The MR images of all subjects were used to estimate volume fraction of femur within the thigh using a common point counting grid (CPCG) with ¼ area fraction i.e. d=0.25 and 0.5cm. The films were placed on a light bow and the CPCG was superimposed, randomly covering the entire image frame (Fig. 1). While only the encircled points (i.e. d=0.5 cm) hitting the thigh including all components of the thigh were counted as an estimate of the reference space (i.e. total thigh volume), all points with and without a circle (i.e. d=0.25 cm) hitting the femur were counted as an estimate of volume fraction of bone structure within the thigh (i.e. V_V (femur, thigh). The femoral volume fraction (VF) value was estimated by means of the following formula.

$$V_V\,(\,femur, thigh)\,\frac{\sum P_{femur}}{4\times\sum P_{thigh}} \qquad (2)$$

where, ΣP_{femur} is the total number of points hitting the femur and ΣP_{thigh} is the total number of points hitting the thigh including the femur. The value obtained is the VF of the femur within the thigh expressed as a percentage. All estimates were made for the left and right thigh independently.

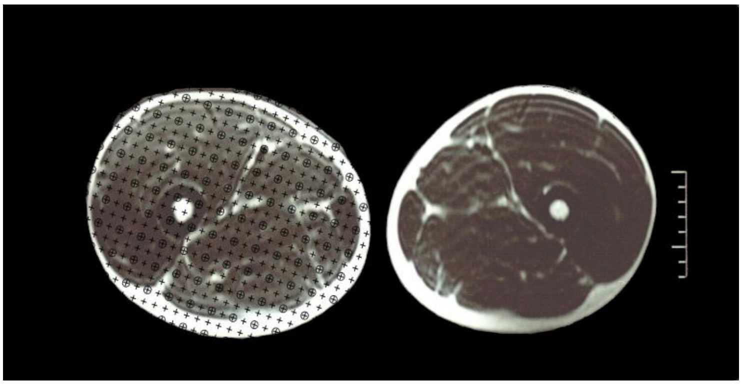

Fig. 1
An axial magnetic resonance image taken from the thigh. A combined point counting grid with ¼ area fraction was superimposed, randomly covering the entire image frame. The encircled points (⊕) hitting the entire projection area were counted as an estimate of the reference volume; all points with and without a circle (+ and ⊕) hitting only the bone sectional surface area were counted as an estimate of the volume fraction of femur within the thigh.

The Coefficient of Error (CE) of stereological estimations was calculated using the formula reported by Gundersen & Jensen [11]. All calculations and other related data were obtained as a spreadsheet using Microsoft Excel. After initially setting up and preparing the formulae, the point counts, formulae and other data were entered for each subject and the final data were obtained automatically.

The Pearson correlation test was performed to analyze the relation between the femoral VF and 30m running time. The right and left side volume and VF values were compared using Student’s t test. SPSS for Windows was used for statistical analysis.

Results

The details of the group, the speed measurements and the results of stereological estimates are given in Table 1. The mean 30m running time was 4.18±0.02 seconds. The mean femoral VF within the thigh was 5.54±0.22 %, the values being 5.51±0.22 % and 5.57±0.24 % for the right and left sides, respectively. There was no statistical difference between values for the right and left sides ($p>0.05$). The analysis of 30m running time and femoral VF showed a negative correlation ($p<0.05$; $r=-0.371$). This means that an increase in femoral VF causes a decrease in 30m running time. The graphic analysis of correlation is shown in Fig. 2.

Table 1
The details of the group, the speed measurements and the results of stereological estimates (SEM is the standard error of mean)

Parameter	Mean	Minimum	Maximum	SEM
Age (year)	17.33	16.00	19.00	0.19
Height (cm)	175.93	163.00	187.00	1.03
Weight (kg)	68.16	61.60	83.60	0.83
30m Speed (Second)	4.18	3.99	4.49	0.02
Femoral VF Right (%)	5.51	3.81	7.94	0.22
Femoral VF Left (%)	5.57	3.80	8.52	0.24
Femoral VF Both (%)	5.54	3.80	8.23	0.22

Regression analysis of 30m running time and femoral VF were predicted as follows:

$$\text{30m running speed} = 4.4 - 0.038 \times \text{femoral VF} \quad (3)$$

where, 4.4 and 0.038 are constants. If one obtains the femoral VF of any subject, it is possible to predict the 30m running time of the same subject using the proposed formula.

The mean point-counting time was 32 minutes 19 seconds (minimum 23:23; maximum 53:08). The mean coefficient of error (CE) of the volume fraction estimates for the entire thigh and the bone tissue were 0.07% (minimum 0.06%; maximum 0.08%) and 0.024% (minimum 0.014%; maximum 0.031%), respectively.

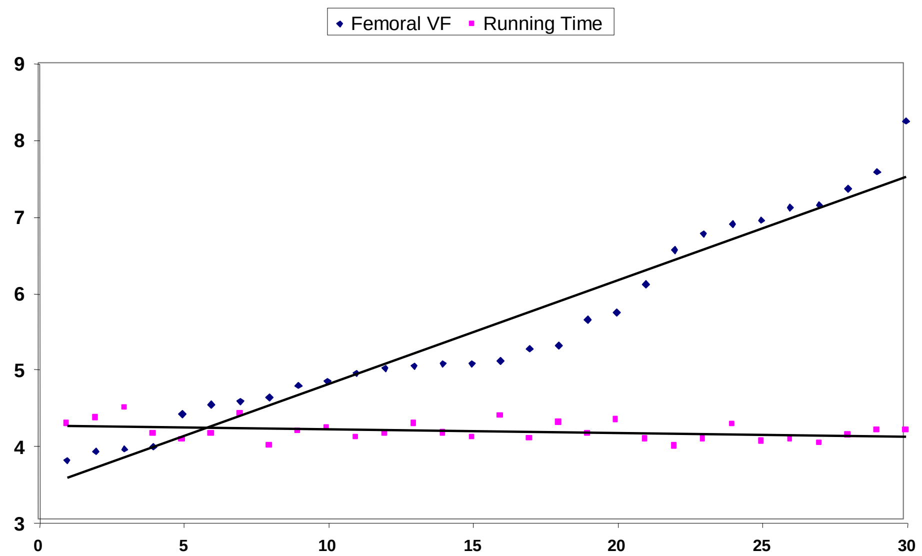

Fig. 2
Graph showing the relation between 30 m running time and femoral VF. An increase in femoral VF causes a decrease in 30 m running time

Discussion

Speed is the ability to perform a movement within a short period of time [24]. It is a determinant ability in many sports such as sprinting events, boxing, fencing, team sports, and others. Consequently, speed training is an important concern for nearly every sport. Many factors influence speed development especially heredity, reaction time, the athlete's ability to overcome external resistance, technique, concentration and will-power, and muscle elasticity [6]. The most important part of most sport skills is speed of movement, not reaction time [9]. It has been shown that to improve speed each athlete needs to work on acceleration, starting ability, stride rate, speed endurance, and stride length [17,18].

The frequency of stride is related to the contraction velocity of the muscle and indicates a genetic characteristic. It is affected by external factors such as weather conditions, ground and material, and by internal factors such as the distribution of muscle fibres and the proportion of fats. The proportional distribution of body components should be included in this list. In particularly, we propose that the proportional volume of the bone has an effect on speed.

It is usually agreed that sprint running performance requires the ability to generate a high velocity of shortening in the locomotor muscles. Especially, explosive strength of the leg extensor muscles plays a major role in the performance [16]. Muscle shortening velocity is determined by biochemical (myosin ATPase activity) [3,28] and architectural (fiber length; the number of sarcomers in series) [5,25,29] characteristics. Most studies on the capacity for shortening velocity in leg muscles and sprint running performance have focused on biochemical properties. Several studies have demonstrated that both male and female sprinters have a high percentage of fast-twitch muscle fibers in the leg muscles [4,8,30]. Furthermore, maximum running speed and 100-m sprint running performance are related to the percentage of fast-twitch muscle fibers [22]. Certainly, top sprinters have faster muscle fibers and greater muscular power available to reposition their limbs [8,10,12,13]. Thus, maximum speed in running is associated with the proportion of fast-twitch muscle fibers in which are biochemical properties are particularly relevant [1,15,22,30].

On the other hand, it is believed that the dominating factors effective in the speed of fast human and animal sprinters are increasing stride distances and stride frequencies. It has, however, been reported that the differences between the top speeds of runners stems from the amount of power applied on the ground rather the stride frequencies and stride distances [31].

As far as we are aware no study has examined the relationship between the proportional values of individual components of the leg, i.e. muscle, bone, skin, fat and other tissues, and speed. In this context, there is little information on the interaction between movement dynamics and bone size. In the present study, which deals with the volume ratio of the bone, we detected a highly negative correlation between the 30 meter running times and the VF of the femur to the entire thigh region. Accordingly, the 30 meter running time decreases as the VF of the bone in the thigh region increases. In other words, speed increases as the VF of the bone increases. Not only does the increase in volume of the bone have a positive effect on speed, but it also decreases the risk of bone fractures [23]. This indicates the need to increase endurance limits of the body through comprehensive physical exercises.

The estimation of the VF using the stereological approach applied in this study provides unbiased data about the volumetric quantities of the thigh. The values obtained in this way are reliable and reproducible. Moreover, the stereological approach could be easily applied without altering routine radiological imaging techniques and the obtained data show little inter-observer variation [2,27].

New stereological methods provide information for researchers so that they can make appropriate changes in their sampling strategies and point density of the grids by estimating the CE. A coefficient of error lower than 5% or sometimes 10% is within an acceptable range. The mean CE for VF estimates in this study for whole thigh and bone tissue were 0.07% and 0.024%, acceptable ranges for the estimates[7,11,21,26,27].

The speed is a very important parameter in football and it could be a determining factor of sportsmen with high performance. This study has proved that the speed, together with other biochemical and architectural features, is related to the VF of bone. It is possible to make use of these data practically on a large scale for instance to select fast sportsman or to design exercises for acquiring speed. According to our findings, when selecting football players, favoring those who have a high femur volume will have a considerable influence on raising the performance. It has been concluded that in cases which require an increase in speed, it is necessary to exercise to increase VF of the bone in the thigh region, and that it is possible to monitor the communality of components in the thigh region which is likely to occur during these exercises.

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