MEDIAL GASTROCNEMIUS MUSCLE ARCHITECTURE IN ARTISTIC AND RHYTHMIC GYMNASTS

[1]Natália Batista Albuquerque Goulart,[1,2]Fernando de Aguiar Lemos, [1,3]Caroline Pieta Dias, [1]João Carlos Oliva, [1]Marco Aurélio Vaz

[1]Exercise Research Laboratory, School of Physical Education, Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil

[2]Faculty Cenecista of Osório, Faculty of Physical Education, Osório, RS, Brazil

[3] Physical Education Course, Faculty of Serra Gaúcha, Caxias do Sul, RS, Brazil

SUMMARY

The purpose of this study was to compare the medial gastrocnemius (MG) muscle architectural characteristics between artistic gymnasts (AG) and rhythmic gymnasts (RG). MG fascicle length, fascicle pennation angle and muscle thickness were measured by ultrasonography in 10 elite female AG and 10 elite female RG. Images were captured from the dominant limb at rest with neutral ankle joint position (0°). Fascicle length (absolute and relative to limb length) was significantly greater in RG compared to AG. However, pennation angle and muscle thickness were greater in AG compared to RG. AG and RG showed different MG architectural characteristics which can be related to their specific athletic requirements.

Key-Words: Muscle Architecture, Ankle, Gymnasts

INTRODUCTION

It is well known that skeletal muscles change their morphology and functionality in accordance to the magnitude of the chronic requirements in daily life activities. Therefore, highly trained athletes show a particular muscle structure related to the physical requirements or functional demands of their sports [1,3]. Ultrasound has been used to assess *in vivo* muscle architecture, i.e., the geometric arrangement of muscle fibers. To date, parameters such as fascicle length, fascicle pennation angle and muscle thickness have been investigated in different plasticity models. However, available information on differences in muscle architecture of competitive sports remains limited. Abe et al. [1] reported longer fascicle length and smaller pennation angle in leg muscles of sprinters compared with distance runners, which appears to favor or increase the shortening velocity for sprinters. Similarly to other sports, artistic gymnasts (AG) and rhythmic gymnasts (RG) are two distinct sports with specific and different skills and physical demands [4]. AG requires a lot of arm and leg strength and power, as well as coordination for performing difficult tumbling/acrobatic exercises. In comparison to AG, RG requires less strength but higher stretching, flexibility and dancing skills. RG uses dynamic apparatus and lower limb movements performed at high speed against resistance. Therefore, the different mechanical demands of these sports may determine specific adaptations in their muscles. Thus, the purpose of this study was to compare muscle architectural characteristics between AG and RG.

METHODS

Subjects: Ten female AG and ten RG were recruited for this study, which was approved by University Ethics Committee in Human Research (2008167). A written informed parental consent was obtained prior to the youngsters' participation in the experiment. Both gymnasts groups consisted of young high performance (elite) gymnasts at the national competition level. Pubertal stages were determined according to the criteria of Tanner [5] by a female researcher. All participants were in tanner stage II-III. Body mass, standing height and lower limb length (taken from lateral maleolus to lateral tibial condyle) were measured in all subjects.

Protocol and data acquisition: Ultrasound images were gathered from the MG muscle (at a proximal point located about 30% between the lateral tibial condyle and the lateral fibular malleolus) [1] using an ultrasound scanner (SSD 4000, 51 Hz, ALOKA Inc., Tokyo, Japan). Images were obtained from the dominant limb, which was determined by the Waterloo dominance test [6]. During the measurements, subjects remained in a sitting position with the knees extended, ankle joint at a neutral position (i.e. 90° angle between the foot and the tibia) and with the muscle relaxed.

Data analysis: MG fascicle length was determined assuming a linear distance between the insertions of the muscle fascicle to the superficial and to the deep aponeuroses. Pennation angle was defined as the angle between the fascicle and the deep aponeurosis, whilst muscle thickness was measured as the linear distance between the superficial and the deep aponeuroses [1-3]. Three measures were used to calculate the mean value of each dependent variable. Fascicle length was normalized to the athletes' lower limb length. All images were analyzed in ImageJ software (National Institute of Health, USA) to determine fascicle length, pennation angle and muscle thickness [7].

Reliability of muscle architecture: To ascertain the reliability of muscle architecture measures, ICCs were computed using six images measured twice by the same evaluator in different days. ICCs from each variable were

rated as highly reliable (>0.75), moderately reliable (0.4-0.75) fairly reliable (>0.4) and poorly reliable (<0.4) [8].

Statistical analyses: Descriptive statistics was conducted to present data in mean and standard deviation values. Normality of data distribution and homogeneity of variances were assessed via Shapiro Wilk and Levene tests, respectively. Age and anthropometrical measures were compared using an independent t-test. For the comparison of muscle architecture parameters between athlete groups a one-way ANOVA was used with a Bonferroni post-hoc test. Significant differences were defined when $\alpha < 0.05$.

RESULTS AND DISCUSSION
There were no significant differences among AG and RG in age (AG, 11.7±1.06 yr; RG, 12.4±1.35 yr), and body weight (37.6±5.85 kg; 41.7±7.48 kg, respectively). Height was significantly greater in RG (152±0.05 cm) compared with AG (144±0.08 cm). ICCs showed high reliability in muscle architecture measures (>0.99).

Absolute and relative fascicle length were significantly higher in RG compared with AG ($F_{(1.18)}$ = 38.025; p<0.001) and ($F_{(1.18)}$ = 12.126; p=0.003). However, AG had a significantly greater pennation angle than RG ($F_{(1.18)}$ = 23.234; p<0.001). Muscle thickness was also significantly greater in AG compared with RG ($F_{(1.18)}$ = 11.204; p=0.004). All skeletal muscle architecture data are presented in Table 1.

It is known that fascicle length plays an important role in determining a muscle's maximum shortening velocity [9-10]. Therefore, muscles with longer fibers are better designed for dynamic fast activities. RG use dynamic apparatus in movements performed at high speed. In rhythmic gymnastics rules, the athletes need to execute movements with directions change (on the ground, in the air and spins over the foot) and they do not stay static during the routine [11]. Thus, the longer fascicle in the RG leg muscle must be related with the physical requirements of this sport, which requires producing force at high contraction velocities in repetitive contractions. A similar rationale can be used for the greater GM pennation angle and thickness in AG. It seems that the artistic gymnastic training emphasizes force production, more specifically,

explosive muscle strength, which is probably linked to the performance of explosive and powerful tumbling and acrobatic elements.

CONCLUSIONS
RG athletes have longer MG fascicle length, while AG athletes have greater pennation angle and muscle thickness. These architectural characteristics appear to be related with specific mechanical demands experienced by these athletes in their specific sports.

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Table 1: Descriptive data on fascicle length (cm), fascicle length relative to limb length (fl/l), pennation angle (°) and muscle thickness (cm) of the medial gastrocnemius (MG) muscle in artistic and rhythmic gymnasts.

Groups	Fascicle length (cm)	Normalized fascicle length (cm/cm)	Pennation angle (°)	Muscle thickness (cm)
Artistic Gymnasts	5.44±0.34[*]	0.19±0.02[#]	14.29±1.39[*]	1.16±0.14[#]
Rhythmic Gymnasts	7.69±0.71	0.22±0.02	12.08±0.41	0.97±0.11

[*]p<0.001, [#]p<0.005; AG vs. RG