Contractile Properties of Quadriceps muscles in Children and Adults

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ABSTRACT

The mechanomyographic (MMG) and electromyographic (EMG) properties of quadriceps femoris muscle function in preadolescent and adult males were examined. The relationship between MMG and absolute force was linear and with identical slopes for both groups, however EMG and absolute force while being linear, differed in the slopes. MMG to relative force (%MVC) is exhibited lower values in preadolescents than adults. The MMG results can be explained by muscle morphology (muscle fiber composition) and metabolism.

INTRODUCTION

Muscle morphology, including volume and cross-sectional area (CSA) is a main factor determining muscular force development in children.[4,9,19] It has been found that CSA correlates with isometric maximal force values during elbow flexion and knee extension in both children and adults.[7,8] Neural factors, however, appear to be acquired prior to the age of 6 years and do not differ between preadolescents and adults.[2] Little is known about the mechanical properties of muscle involved in force generation e.g. motor unit recruitment and rate coding strategies, of preadolescents.

The present study was undertaken to investigate the mechanical properties of force generation in preadolescents and adults using combined mechanomyography (MMG) and electromyography (EMG). The MMG provides an indication of the intrinsic mechanical events involved in force generation, whereas the EMG characterizes the bioelectric properties.[1,5,12]

MATERIALS AND METHODS

Eight preadolescent boys, 9-11 years of age (10.2±0.6 years), and ten male adults, 21-23 years of age (21.8± 0.9 years), participated in this study. After determining the maximal voluntary contraction (MVC), each subject was required to hold six different levels of isometric knee extensions corresponding to 10, 20, 30, 40, 60 and 80% MVC. The MMG was detected by a small and unidirectional accelerometer (8352A2, Kistler) placed over rectus femoris muscle belly, then was amplified by an AC amplifier with a bandpass filter of 5 Hz to 100 Hz (AB-621G, Nihon Koden). The EMG was recorded from bipolar surface electrodes with diameter of 2 cm placed on both sides of the accelerometer 3 cm apart. The EMG signal was connected to an AC amplifier with a bandpass filter of 5 Hz to 1,000 Hz (WEB-5000, Nihon Koden). Knee extension force was monitored by a load cell (GT-30, OG Giken) attached to a semicircular metal frame.

RESULTS

The MVC in the preadolescent group was significantly smaller than that in the adult group (preadolescent 57± 16 Nm; adult 112± 25 Nm). The root mean squared MMG and EMG (rmsMMG and rmsEMG) increased progressively with increasing absolute force in both preadolescent and adult group (Fig.1a). The rmsMMG plots in the preadolescent group overlapped those at the lower levels of force in the adult group. The two regression lines of the rmsMMG were almost identical. The rmsEMG was also related linearly to absolute force

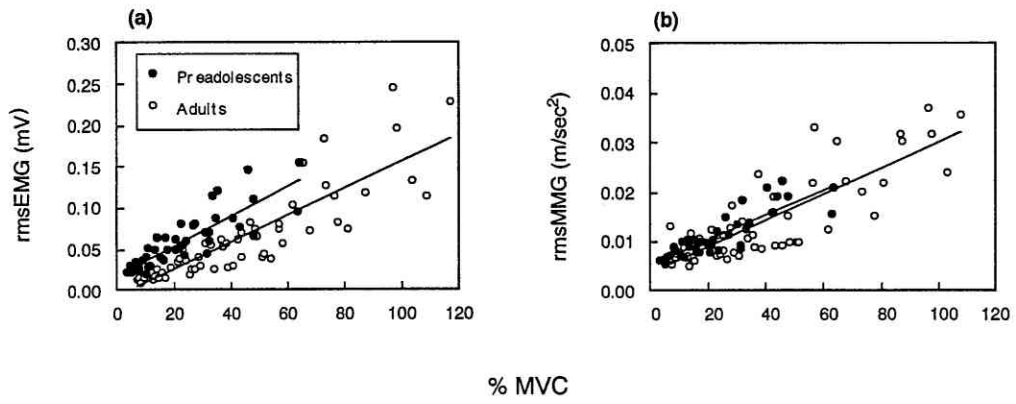

FIGURE 1. Individual plots of the root mean squared EMG (RMS_{EMG}) and MMG (RMS_{MMG}) of quadriceps muscles as a function of absolute force (a) (b). Filled circles indicate preadolescent and open circles indicate adults. (a) Regression line slope of preadolescent is y=2.39x (r=0.85) and adults is y=1.52x (r=0.87). (b) Regression line slope of preadolescent is y=0.184x+5.11 (r=0.81) and adults is y=0.188x+4.02 (r=0.82).

in the two groups. However, the rmsEMG plots and their regression line in the preadolescent group were located above those in the adult group (See Fig.1b).

When the rmsMMG and rmsEMG were expressed as a function of the relative force (%MVC), both preadolescent and adult group demonstrated a progressive increase in the rmsMMG and rmsEMG with increasing %MVC (Fig.2a,b). The increment of the rmsMMG was greater at the levels of force above approximately 40% MVC in both groups. The rmsMMG in the preadolescent group was significantly smaller than that in the adult group at 60% and 80% MVC ($p<0.05$) , whereas the rmsEMG did not show significant difference between the two groups.

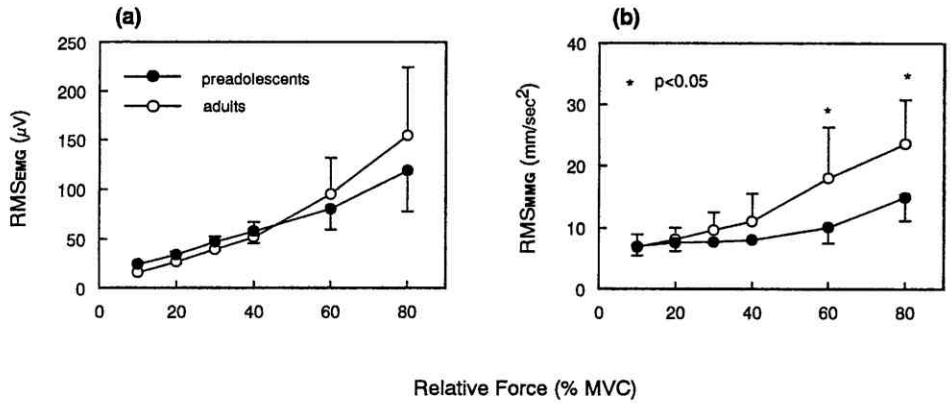

FIGURE 2. Mean values±SD of RMS_{EMG} and RMS_{MMG} of quadriceps muscles as a function of relative force (% MVC) up to 80% MVC (a) (b). (a) The rmsEMG does not show significant difference between the two groups. (b) The rmsMMG in the preadolescent group is significantly smaller than that in the adult group at 60% and 80% MVC ($p<0.05$).

DISCUSSION

The relationship between the MMG and absolute force has been examined previously in biceps brachii muscles[11] and paraspinal muscles,[14] but not in quadriceps muscles. The present study focused on the MMG activity of quadriceps muscles as a function of force. The rmsMMG vs absolute force relationship in the preadolescent group was well fitted by a regression line similar to that in the adult group. Furthermore, the rmsEMG vs absolute force relationship indicated that preadolescent muscle required greater EMG activity to produce the same magnitude of the MMG and force. Takagi[17] documented that the Ca^{2+} uptake activity of the sarcoplasmic reticulum in young people was lower than that in adults. The findings suggest that the MMG is indicative of muscle force in preadolescents as well as in adults as previously reported,[11,14] and the efficiency of the excitation-contraction

coupling in preadolescent muscle is lower.

A moderate isometric force is controlled by varying the number of active motor units (MUs) composed essentially of slow twitch (ST) fibers. As force increases above 30% MVC, a recruitment of fast twitch (FT) fibers occurs in addition to an increase in the discharge rate of ST fibers.[6] The MMG vs %MVC relationship in quadriceps muscles appears to reflect this recruitment strategy.[15,16,20] Namely, the MMG increases progressively with increasing %MVC and its increment greater at levels of force higher than 30% MVC. A similar trend was confirmed from the rmsMMG in the present adult group. The preadolescent group also showed a progressive increase in the rmsMMG, however the increment was smaller than that in the adult group. Thus, the muscle recruitment strategy with respect to ST and FT fibers appears to be different between adults and preadolescents.

The difference may be caused by the immaturity of the muscle fiber composition and a muscle metabolism. The percentage of FT fibers in preadolescent muscles is smaller than that in adult muscles although the total number of muscle fibers is not different.[5,12] Furthermore, the FT fiber produces a higher level of phosphofructokinase (PFK) enzyme activity relating to the glycolysis production compared with the ST fiber.[13] The PFK enzyme activity in adolescent boy muscle is approximately one-third of that in male adult muscle.[4] These facts seem likely to explain the smaller increment in the MMG vs %MVC relationship in the preadolescent group.

In conclusion, the MMG reflects the force development properties of muscle. The root mean square MMG to relative force (% MVC) relationship or preadolescents lags behind that of adults, whereas the root mean square EMG to relative force relationship parallels that of adults. These observations about the mechanical properties of force generation in preadolescents are consistent with the known alteration in fiber composition and glycolytic enzyme levels with maturation and these physiological differences may explain the mechanical events.

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