Maturation of mechanical properties of plantar flexor muscles in prepubertal children of the Northeast of Brazil

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Introduction

To assess muscle mechanical properties in humans, hydraulic or motorized ergometer devices are often used in laboratories (Hof, 1998; Tognella et al., 1997). These ergometer devices are heavy equipment, and it is difficult to conduct experiments in other locations in order to evaluate different populations in their own environments. Therefore, a transportable ankle ergometer (Lambertz et al., 2008) was designed to conduct field experiments on mechanical properties of the triceps surae. To show the reliability of this new device, a validation study was conducted on healthy prepubertal children and compared to data of the literature.

Methods

The technical support of the present transportable ankle ergometer device (Lambertz et al., 2008) has been derived from an ankle ergometer already used in adult subjects (Goubel and Pertuzon, 1973). For this study, twenty-eight 7- to 9-years old prepubertal children (15 girls and 13 boys) were tested in a school in Recife/PE. The nutritional status was determined according to the guideline of the World Health Organization (2007). Thus, all children were classified as euthrophic. Elastic properties of an adult metropolitan city reference group were also tested.

The experimental protocol has been described in detail elsewhere (Grosset et al., 2005; Lambertz et al., 2003) but will be reviewed shortly here. After placing the subject on the adjustable seat (knee 120º and ankle 90º), the maximal motor direct response (M_{max}) was elicited by applying a supramaximal electrical stimulation to the posterior tibial nerve. The stimulus intensity was adjusted so as to obtain the M_{max} of Sol, allowing the measurement of twitch force. Five twitches were recorded. Then, force from a maximal voluntary contraction (MVC) was determined in plantarflexion under isometric conditions. Three attempts were carried out and the maximal value was considered as MVC of the day. Twitch and MVC force were then converted to torque. Finally, elastic properties of the musculotendinous (MT) complex were assessed by means of a quick-release technique adapted for *in vivo* experiments (Goubel and Pertuzon, 1973). Quick-release movements were achieved by a sudden releasing of the footplate, while the subject maintained a submaximal voluntary isometric force in plantarflexion (25%, 50% and 75% of MVC).

Data processing consisted in analyzing the peak twitch torque (Pt), contraction time (CT) and half relaxation time (HRT) of each twitch record. The results of the five records were then averaged. MT stiffness (S) was calculated as the ratio between variations in angular acceleration Θ'' (as the second derivative of angular displacement Θ) and Θ multiplied by inertia I, as expressed by the formula: $S = \Delta\Theta'' / \Delta\Theta * I$. Then, MT stiffness values were related to torque. The slope of the linear angular stiffness-torque relationship so obtained was defined as a stiffness index of the MT complex (SI_{MT}). A one-way ANOVA test was carried out to analyze the effect of prepubertal age on the parameters. Statistical significance was set to $P<0.05$. Values are mean ± SEM.

Results

The results of the analyzed parameters are given in table 1 and figure 1.

	7-years	8-years	9-years
MVC (Nm)	17.8±4.4	24.8±8.4	34.6±8.7
Pt (Nm)	4.00±0.7	7.2±0.4	11.1±0.8
CT (ms)	98.4±1.8	91.4±0.9	97.2±4.4
HRT (ms)	89.6±6.5	94.9±5.7	85.9±2.8

Table 1: Data of the tested parameters in children aged 7- to 9-years.

ANOVA analyses indicated significant differences for MVC ($F [2, 23] = 3.93$; $P = 0.039$) and Pt ($F [2, 23] = 8.20$; $P = 0.0039$). As for the twitch kinetics, no significant differences were found between the age groups for CT ($F [2, 23] = 1.12$; $P = 0.35$) and for HRT ($F [2, 23] = 0.62$; $P = 0.55$).

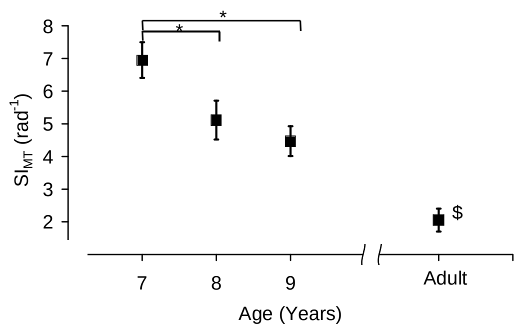

Figure 1: Evolution of musculotendinous stiffness index (SI_{MT}) with age for children and adult subjects. * indicates significant differences between the child groups and $ indicates significantly different from the child groups at P < 0.05 from ANOVA analysis. Data are mean ± SEM.

Discussion

The maximal voluntary torque in isometric conditions increases with the age of the prepubertal children. This evolution is similar to those reported for European prepubertal children (Lambertz et al., 2003; Grosset et al., 2005). As reported by these authors, the increase in muscle mass with age as well as an improvement in the voluntary activation capacities with age (Grosset el al., 2008) can be predominant factors. As for twitch torque in induced condition, the linear increase in Pt with age can be mainly attributed to the increase in muscle mass with age, since the Pt is independent of voluntary activation capacities. When considering that the twitch kinetic parameters induced *in vivo* gives information about the muscle fibre distribution (Rice et al., 1988), the fibre type distribution seems to be the same between the children aged 7 to 9 years. This is in accordance with data about fibre type distribution during maturation. Indeed, Elder and Kakulas (1993) reported that the fibre type distribution profile is already established at the age of 3 to 4 years.

The present study reported changes in the elastic properties of the muscle-tendon complex with age of prepubertal children. The evolution of the present results was similar to those reported for European prepubertal children (Lambertz et al., 2003). It is well known that MT elastic properties can be distinguished in an active fraction (cross-bridges) and a passive fraction (tendon). In the present study, the decrease in SI_{MT} with age cannot be explained by differences in the active fraction, i.e. the fibre type distribution, since it is known that fibre differentiation is accomplished at the age of 3 to 4 years (Elder and Kakulas, 1993). With regard to the passive elastic properties, Kubo et al. (2001) reported an increase in tendon stiffness of the vastus lateralis for children aged between 11 to 15 years. Thus the paradoxical decrease in SI_{MT} can not be explained only on the assumption of differences in the active and passive fraction of the muscle-tendon complex. Therefore, as proposed by Lambertz et al. (2003) changes in the activation capacities can influence musculotendinous stiffness measurement. These results confirm data of the literature (Lambertz et al., 2003) in Brazilian prepubertal children.

Conclusion

The present results reported the maturation process of prepubertal children aged in the narrow age span of 7 to 9 years. The quantification of the mechanical properties using the transportable ergometer device showed that the maturation of the muscles in prepubertal children in the Northeast of Brazil is similar to those reported for European prepubertal children. These data can be used as a reference target group for clinical studies in relation to malnutrition.

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