Influence of malnutrition on the maturation process of mechanical properties of plantar flexor muscles in prepubertal children

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Introduction

Malnutrition in the Northeast of Brazil is still a preoccupying factor from a point of view of public health with possible irreversible consequences in the development of muscle function. Recently, our group reported that some biomechanical parameters in isolated soleus (Sol) muscle of rats, like twitch force, maximal shortening velocity and series elastic stiffness were modified due to malnutrition during prenatal (Barros et al., 2004) or neonatal period (Toscano et al., 2008). It can be questioned, whether early malnutrition has consequences on the normal maturation process of mechanical properties of muscles in humans. Such maturation process of the mechanical properties of the triceps surae muscle group has been already described in normal prepubertal children (Grosset et al., 2005; Lambertz et al., 2003). The aim of the present study was to quantify the force production capacities, as well as the elastic properties of the triceps surae muscle group in malnourished prepubertal children.

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, forty-seven 9-years (± 2 months) old prepubertal children were tested in a rural village of Pernambuco, Brazil. The nutritional status was determined according to the guideline of the World Health Organization (2007). Thus, 25 children were classified as euthrophic (E) and 17 children were classified with a risk (R) nutritional status. Elastic properties of a euthrophic metropolitan city reference group of prepubertal children aged 7 to 9 years 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 child 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}). Statistical analyzes included the comparison between E and R group using a Student t-test for unpaired changes. 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.

	Risk	Euthrophic	P value
MVC (Nm)	5.9 ± 0.4	8.7 ± 1.2	P = 0.05
Pt (Nm)	1.8 ± 0.2	2.9 ± 0.3	P = 0.03
CT (ms)	87.9 ± 4.4	88.0 ± 2.9	P = 0.94
HRT (ms)	91.1 ± 8.2	99.4 ± 4.5	P = 0.59
SI_{MT} (rad^{-1})	5.8 ± 0.4	4.2 ± 0.5	P < 0.01

Table 1: Data of the tested parameters in children of the euthrophic and risk group. P indicates the significance level.

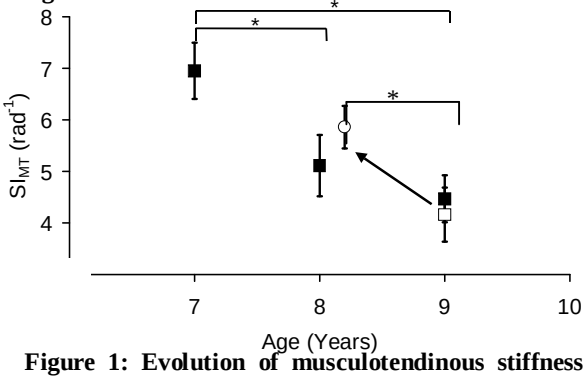

Figure 1: Evolution of musculotendinous stiffness index (SI_{MT}) with age for euthrophic children (■ and □) and children with risk of malnutrition (○). * indicates significant different at P<0.05.

Discussion

The present study reported the consequences of malnutrition on mechanical properties of the triceps surae muscle group. We showed that Pt and MVC torque was significantly lower in R compared to E. In children, Bénéfice et al. (1999) observed a reduction in muscle mass due to malnutrition. These results are in accordance with those obtained on isolated, 25 days old Sol muscles of rats (Barros et al., 2004; Toscano et al., 2008). Muscle atrophy due to malnutrition is suggested. As for the twitch kinetics, CT and HRT did not show significant differences with the nutritional status of the prepubertal children. These results are in accordance with those reported on isolated Sol muscle when malnutrition was imposed during the prenatal period (Toscano et al., 2008), but opposite to those obtained when malnutrition was imposed during the neonatal period (Barros et al., 2004). When considering that twitch kinetic parameters induced *in vivo* gives information about the muscle fiber distribution (Rice et al., 1988), it can be argued that the fiber type distribution is the same between R and E. Nevertheless, differences in MT stiffness properties were also put forward to influence twitch kinetics (Toscano et al., 2008).

Higher SI_{MT} values were found between R and E. This result is in accordance with those showed on isolated Sol muscle of rats, where an increase in series elastic stiffness was found when malnutrition was imposed during the prenatal period (Toscano et al., 2008). Malnutrition during the neonatal period led to a trend of increased series elastic stiffness of isolated Sol muscle (Barros et al., 2004). Since it is well known that series elastic properties can be distinguished in an active fraction (cross-bridges) and a passive fraction (tendon), it was hypothesized that changes in the passive fraction counteracts the stiffness changes of the active fraction (Barros et al., 2004; Toscano et al., 2008). The influence of opposite evolution of the active and passive fraction has also been proposed for human experiments (Pousson et al., 1991). In the same way, differences in the maturation process of the active and passive fraction of the MT complex can be put forward for malnourished prepubertal children. Furthermore, differences in the muscle activation capacities exits in normal prepubertal children in function of age (Grosset et al., 2005, Lambertz et al., 2003). Thus, when also present in malnourished prepubertal children, over-activation can be a further mechanism.

This is illustrated in figure 1. As reported by Lambertz et al., (2003), the paradoxical decrease in SI_{MT} with age was mainly attributed to coactivation of the tibialis anterior. Brazilian prepubertal children showed this same evolution. Furthermore, there were no differences in SI_{MT} between prepubertal children of the rural village and children of the metropolitan city. The higher SI_{MT} value in prepubertal children with risk of malnutrition can be then attributed to a delay in the maturation process of the neuromuscular system. This is indicated by the flash in figure 1. This hypothesis is supported by data from motor ability tests, were a delay of 10 months in balance was reported (personal communication of Paiva MG).

Conclusion

In conclusion, these results suggest that differences in the force production capacities are due to atrophy of the muscles. It is hypothesized that the higher SI_{MT} values in prepubertal malnourished children is due to different mechanisms of the voluntary activated MT complex, what lead to a delay in the maturation process of the neuromuscular system EMG analyses are suggested.

Acknowledgements

This study was supported by grants from CNPq - Brazil. Dr Daniel Lambertz is a CAPES Visiting Professor at the Departamento de Nutrição.

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