Influence of functional adaptation on the torque-angle relation

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Introduction
Functional demand has been proposed as one of the responsible factors for adaptation of skeletal muscle (Caplan et al., 1988; Herzog, 1996). Muscle fibers increase their structural and functional capacity in response to overload. Different types of overload should determine different types of structural and functional adaptations in skeletal muscle. Classical ballet dancers and volleyball players, for example, show different demands for the ankle plantar-flexor (PF) muscles, where classical ballet dancers use the PF muscles in a shortened position, while the volleyball players use the same muscles in a lengthened position. The functional adaptation due to these different types of training may be responsible for changing the force production capacity, and, consequently, for modifying the force-length (or torque-angle) relationship of these two groups. Therefore, the purpose of this study was to compare the torque-angle (TA) relation and the electromyographic (EMG) activity of the PF muscles in these two groups.

Methods
Thirty-six female subjects (ballet dancers n=14; volleyball players n=22) participated in the study. Peak torque (Tmax) of the PF muscles was evaluated during maximal voluntary isometric contractions in seven different ankle angles (-10°, 0°, 10°, 20°, 30°, 40°, 50°) using a Cybex Norm isokinetic dynamometer. Electromyographic signals were obtained from the gastrocnemius medialis (GM) and soleus (S) muscles by means of surface electrodes in a bipolar configuration for all angles. Root mean square (RMS) values were calculated. Tmax and RMS values were normalized for each subject. Linear regression was used to evaluate the Tmax and RMS behavior as a function of angle. A two-way analysis of variance for repeated measures was used to evaluate possible statistical difference for each measured parameter (torque, RMS, ankle angle and group), as well as to test for interaction. Contrasts were used to determine the difference among the several ankle angles. One-way analysis of variance for repeated measures was used to determine statistical difference within groups when interaction was present. The level of significance adopted was 0.05 for all tests.

Results & Discussion
The torque behavior as a function of ankle angle was different between the two groups in all ankle angles studied (Figure 1). A linear relationship was observed between Tmax and ankle angles for both groups. This result is in agreement with the results of Sale et al. (1992) for PF muscles and of Herzog et al. (1991b) for gastrocnemius muscle, which showed that PF muscles work predominantly in the ascendent limb of the force-length relation. However, a leftward shift in this relation was observed for the ballet dancers group compared to the volleyball players, where the ballet dancers had higher torque values in all ankle angles studied with the exception of -10° of PF (shortened position of PF muscles). This leftward shift of the torque-angle relation (towards shorter muscle length) could be explained by a decrease in the number of sarcomeres in series in the PF muscles. In addition, the PF torque did not increase between the ankle angles of 0° and -10° for the ballet dancers group. This result is in agreement with the results of Kitai and Sale (1989) who trained human subjects with the PF muscles in a lengthened position (0° of PF), and showed evidences of a force plateau in longer muscle lengths of PF muscles after training. These authors suggest that their findings would be explained by a change in the number of sarcomeres in series, what has already been shown to occur in animal studies (Koh, 1995; Koh e Herzog, 1998).

According to Herzog et al. (1991a), the functional adaptation, responsible for modifying force capability in skeletal muscle, may be associated with 3 phenomena: (1) intrinsic differences in force production; (2) differences in muscle activation/stimulation; or (3) a combination of these two phenomena. Assuming that functional adaptation was exclusively related to the structural changes in the skeletal muscles, then
no differences should be observed in muscle activation/stimulation of the PF muscles between the two groups, which was not the case in this study.

RMS values showed an opposite behavior between the two groups. While volleyball players showed increased RMS values for GM and S muscles as the PF angle decreased, the RMS values of the ballet dancers increased for GM (Figure 2), but not for S, as the PF angle increased (Figure 3). This different behavior of the RMS values between the groups showed that changes in the electrical activity of PF muscles were also responsible for the differences observed in the force capability in the different ankle angles. The higher force capability of ballet dancers in shorter muscle lengths is in agreement with the higher levels of muscle electrical activity produced in these muscle lengths. This may possibly explain the force production differences observed between the two groups.

**Figure 1.** Normalized PF torque-angle relation for the ballet dancers and volleyball players (mean ± standard error; * = p<0.05).

**Figure 2.** Normalized RMS values of GM in the different ankle joint angles for the ballet dancers and volleyball players (mean ± standard error; * = p<0.05).
Figure 3. Normalized RMS values of \( S \) in the different ankle joint angles for the ballet dancers and volleyball players (mean ± standard error; \(* = p<0.05\)).

The above results support the hypothesis that systematic physical activity is responsible for changes in the skeletal muscle force production capability. These changes may be associated with the different intrinsic muscle properties, and with differences in the muscle activation/stimulation processes. The magnitude of the contribution of each of these factors remains difficult to determine.

References

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