Abstract  The purpose of this study was to show that velocity-specific training may be implicated in modifications in the level of coactivation of agonist and antagonist muscles. Healthy males ($n=20$) were randomly placed in to two groups: one group trained using concentric contractions ($n=12$), the other was an untrained control group ($n=8$). The training group underwent unilateral resistance training at a level of 35 (5)% of a one-repetition maximal contraction of the elbow flexors, executed at maximal angular velocity. Training sessions consisted of six sets of eight consecutive elbow flexions, three times per week for a total of seven weeks. The velocity of the ballistic movements executed during training were measured using an optoelectronic measuring device (Elite), both at the beginning and at the end of the training period. Subjects were tested pre- and post-training during isokinetic maximal elbow flexions with constant angular torque (CAT) at 90° ($0° = $ full extension), and at different velocities (60, 120, 240 and 300° · s$^{-1}$) for concentric actions, and −60 and −30° · s$^{-1}$ for eccentric and isometric contractions at 90°. In order to verify the levels of activation of the agonist biceps brachii (BB) muscles and antagonist triceps brachii (TB) muscles during maximal voluntary activation, their myoelectrical activities were recorded and quantified as root mean square (RMS) amplitudes, between angles of 75 and 105°. The results show that mean angular velocities between elbow angles of 75 and 105° were similar before [302 (32)° · s$^{-1}$] and after [312 (27)° · s$^{-1}$] the training period. CAT significantly increased measures at angular velocities of 240 and 300° · s$^{-1}$ by 18.7% and 23.5%, respectively. The RMS activity of BB agonist muscles was not significantly modified by training. Post-training normalized RMS amplitudes of TB antagonist muscles were inferior to those observed at pre-training, but values were only significantly different at 300° · s$^{-1}$. In conclusion, in this study we attempted to show that an increase of CAT to 240 and 300° · s$^{-1}$, though velocity-specific training, may be due, in part, to a lowering of the level of coactivation.

Key words  Elbow flexors  ·  Isokinetic angular torque  ·  Concentric training  ·  Velocity-specificity principles  ·  Antagonist coactivation

Introduction

The velocity-specific training effects derived from fast or slow contractions are generally believed to involve physiological (Coyle et al. 1981; Narici et al. 1989) and/or neural muscular adaptations (Milner-Brown et al. 1975; Moritani 1993). A large majority of the literature has suggested that muscular force gains due to slow-velocity resistance training are specific, and that fewer adaptations occur outside a specific training velocity (Moffroid et al. 1969; Lesmes et al. 1978). However, high-velocity training has resulted in some controversy with regard to the resulting training adaptations. Kanehisa and Miyashita (1983) showed that knee extensor training at 5.24 rad · s$^{-1}$ improved exclusively isokinetic torque at this velocity. Caiozzo et al. (1981) and Ewing et al. (1990) have also suggested that gains in torque are more evident at high angular velocities following fast-velocity concentric training. Alternatively, however, other studies have shown that high-velocity training also produces significant increases at low angular velocities (Coyle et al. 1981; Dudley and Djamil 1985).

It is possible that the velocity-specificity principle is associated with a selective recruitment of fast motor units in agonist muscles (Coyle et al. 1981), and the ability to recruit more motor units during the activity experienced with training (Komi et al. 1978). An increase in the recruitment of motor units over larger force ranges also appears to be induced by specific training contractions (Bernardi et al. 1996). It has recently been shown that the type of contraction (concentric or
isomeric) appears to have only a secondary role in the velocity-specificity principle. The different modes of torque development (slow or rapid) could be the more determining factor in this principle (Behm and Sale 1993). However, the torque measured is a result of both agonist and antagonist muscular group torques (i.e., net torque). Antagonist cocontractions are frequently used to increase the mechanical stability of a joint, and are also used during prehension. Baratta et al. (1988) deduced that the negative participation of the hamstrings also used during prehension. Baratta et al. (1988) deduced that the negative participation of the hamstrings on the isokinetic knee extension torque should be about 10%. Suggestions made to explain specific gains could be in line with a role for antagonist muscles. In addition antagonist coactivation levels and timing both change with joint velocity; therefore, the net torque can change (Hagood et al. 1990). Moreover, it has been shown that the coactivation phenomenon depends upon the subjects’ training status and could explain the differences in isokinetic torques observed between sedentary and highly skilled subjects (Person 1958; Baratta et al. 1988; Amiridis et al. 1996).

The purpose of the study presented here was to evaluate the possible specificity of torque gains following fast velocity-specific training, and to determine the relationship between the degree of antagonistic cocontraction and subsequent isokinetic gains.

### Methods

#### Subjects

Twenty-four male physical education students [mean (SD): age 23.4 (0.6) years; height 178.4 (7.1) cm; mass 76.7 (6.9) kg] participated in this study. They were randomly placed into two groups, one that trained using concentric contractions \( n = 12 \), the other served as a control group \( n = 8 \). All of the subjects were informed of all risks associated with the study before giving voluntary written consent for their participation. The study was approved by the Regional Ethics Committee, and informed consent was obtained prior to participation from all of the subjects.

#### Training protocol

Free-weight-training protocol: Subjects performed six sets of eight concentric elbow flexions of the dominant arm. The subjects’ elbow was placed within a support that enabled movements to be made in the vertical axis (see Fig. 1, top). They were asked to execute the training movement at maximal velocity, with a load corresponding to 35 (5)% of each subject’s one-repetition maximum (1RM) in order to execute rapid ballistic movements. The range of motion of exercise training was 105 (10)°. A rest interval of 3 min was provided between each series of flexions. Training was undertaken three times per week for a period of 6 weeks. Subjects determined their 1RM during the week of familiarization using weight increments that they chose. At the end of each week maximal tests were performed and loads corresponding to a 1RM were updated. The angular velocity of the movement was recorded and analysed using an optoelectronic measuring device (Elite) between 75° and 105° \( (0° = \text{full extension}) \). This 30° range was chosen to allow a comparison with angular measures obtained from isokinetic data that utilized constant angular torque (CAT). For each subject, one set of the exercise training series was randomly selected for angular velocity analysis during the first and last weeks of training. The Elite system consisted of two TV cameras that detected retroreflective markers at a sampling rate of 100 Hz. The cameras were placed 4 m from the subject. The markers consisted of plastic spheres of 8 mm in diameter that were covered with reflective material (accuracy, 1/3000 of the working field). Since the field used was 2 m × 2 m, the accuracy of the system was in the order of 0.7 mm. Marker images recorded by the cameras were processed for real-reconstruction-time shape recognition. The position in space of three passive markers, including two links, was recorded. Two markers were fastened onto the skin at the following points: (1) the shoulder, on the acromial process, and (2) the lateral condyle of the elbow. A third marker was attached to the load.

#### Experimental procedure

Biomechanical tests were carried out using a Biodex (Biodex, Shirley N.Y., USA) isokinetic dynamometer (validated by Taylor et al. 1991), which allowed the determination of instantaneous muscle torques at various pre-set constant angular velocities. Subjects were made familiar with the Biodex dynamometer three 20-min sessions during the week preceding training. They were positioned in the apparatus according to the Biodex Multi-Joint System User Manual and were seated beside the dynamometer with both the dominant arm and forearm supported in the horizontal plane. The forearm was tightly fixed in a gutter with belts, and the wrist was placed in the neutral position (between supination and pronation). The axis of rotation of the dynamometer was aligned with the epiphroclea-epicondyle axis of the arm. Following a standardized warm-up (three submaximal repetitions at each experimental angular velocity), subjects were asked to perform maximal voluntary elbow flexions after a pause of 2 s at the extreme angular position of the range of motion \( 0°; 120° (0° = \text{full} \)