QUADRICEPS TORQUE SHARING OF SOCCER ATHLETES, BY AN EMG-DRIVEN MODEL, AFTER A FORCE TRAINNING PROGRAM.

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Abstract: Muscle strength and power training are factors for achieving high performance in soccer players. *Quadriceps femoris* (QF) muscle must to be able to bear the demands of soccer players tasks. The purpose of this study is to determine the relative contribution of each of QF components to the submaximal knee extension torque by EMG-Driven model in a group of soccer players, before and after traditional hypertrophy training. Torque signal and surface EMG were synchronously acquired from *vastus intermedius* (VI), *vastus lateralis* (VL), *rectus femoris* (RF) and *vastus medialis* (VM) muscles. The EMG signal was processed to feed an EMG-Driven model as excitation signals. QF pre-training torque sharing patterns were: 34% for VL, 31% for VI, 24% for VM and 11% for RF. After training, this distribution altered to: 34% for VL, 30% for VI, 24% for VM and 12% for RF, but significant statistical differences was not found. There were no significant statistical differences between measured and estimated torques. The mean RMS error between dynamometer and model estimated torques was 13.11±1.97% and 20.83±3.10% before and after training, respectively, with no significant statistical difference (Z= -1.48; P = 0.13). Traditional training did not altered relative contribution QF components to the knee extension torque.
Keywords: EMG-Driven, quadriceps, soccer players, training.

Introduction

Muscular strength is an important factor to determine the success of high performance athletes, as soccer players [1]. Previous studies analyzed the effect of strength and power training on the motor performance (strength, power, speed, agility and endurance) in soccer players [2-3]. These studies showed that the characteristics of the training, such as exercise type, number of sets, repetitions, angular velocity and load intensity can influence the muscular power.

Soccer requires the player to perform, constantly, tasks as salts, acceleration, deceleration and running, which can generate injuries in the knee structures [4]. For such reasons, the knee extensor muscle - *quadriceps femoris* (QF) should be able to bear the demands of these tasks. In soccer players, the QF imbalance between the torque of dominant and non-dominant limbs has been analyzed [5], as well as the relationship between the flexor and extensor knee torques [6]. However, little attention is given to torque sharing among QF components: *rectus femoris* (RF), *vastus lateralis* (VL), *vastus medialis* (VM) and *vastus intermedius* (VI).

Determining the individual contribution of each QF component to the knee torque is a difficult task. EMG-Driven models allows estimating muscle forces using electromyography (EMG) signals, taking into account muscle dynamics and a number of parameters of the muscle structure [7]. Some studies applied EMG-Driven models to assess the role of QF during gait [8] and iso-metric contractions [9 – 11].

Therefore, the purpose of this study was to estimate the relative individual torque contributions among RF, VL, VM and VI, during submaximal knee extension torque of soccer players. The experiments were performed before and after a force training program.

Materials and methods

Sample – Nine soccer players healthy men participated in the study. Protocol was approved by the Research Ethics Committee of Clementino Fraga Filho University Hospital (N.127/13). Volunteers were informed about the procedures and signed the terms of consent.

Force training – The training was applied out of the competition period. The exercise protocol was established by the period of three months. The exercises were: squat in Smith machine and knee extension machine. Before each training session, all subjects performed specific warm-up of 20 repetitions with 50% of the load used in the first exercise section. The program was divided in three sessions per week. The first day was conducted with two sets of 12-15 maximum repetitions (MR), the second with three sets of 8-10 MR and the third with four sets of 4-6 MR. The load was adopted as a function of the subject resistance. Voluntaries were verbally encouraged during all series to perform the series until concentric contraction fails. Total of sessions was 36.

Model nominal parameters – Physiological Cross Sectional Area (PCSA), maximum muscle tension (σ) and pennation angle were individually estimated. The

PCSA and σ were calculated as suggest by Menegaldo and Oliveira [9]. Pennation angle was measured by means of ultrasonography. Other muscle architecture parameters were obtained from literature (OpenSim Lower-limb Model). Muscle thickness (MT) was measured in US images as a variable for hypertrophy [12].

EMG acquisition – VI is a deep QF component and the electrodes were placed with a special protocol, as suggested by Watanabe and Akima [13]. A region in the lateral-distal third on thigh tracked with ultrasonography served to position a pair of electrode. For RF, VL and VM, SENIAM [14] protocol was followed to place the electrodes. Maximal isometric knee extension voluntary contraction (MVC) was tested for each subject in a dynamometer (Biodex System 4, New York, EUA), with the knee flexed 100°. Two repetitions of 5 seconds were performed, with one minute interval. The subjects then followed a 40% MVC sustained contraction during 40 seconds, following a visual feedback target on a screen. Surface EMG from the RF, VL, VM and VI were collected, synchronously with the torque signal from the dynamometer, in an acquisition module (EMG-USB2, OTBioeletronica, Italia). Raw EMG signals, sampled at 2048 Hz, were band-pass filtered (10-500 Hz), rectified and low-pass filtered (6th order digital Butterworth, 2 Hz). The submaximal excitation input signal to the muscle model was normalized by the processed EMG MVC test.

Modeling – Muscle dynamics comprises two steps: activation dynamics and contraction dynamics. The first simulates the delay between neural excitation and muscle activation, while the second models the relationship between activation and force (Figure 1). The QF torque output was calculated by sum of the four individual muscle forces, estimated by the EMG-driven model, multiplied by the respective moment arms (Figure 2). The difference between measured and estimated torque was calculated as previously [9] (Figure 3).

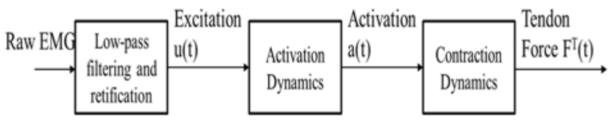

Figure1: EMG-Driven model structure.

Statistical analysis - The Wilcoxon signed ranks nonparametric test was used to verify statistical differences between: (1) the relative contribution from each of the QF components, pre and post-training (intra-muscles); (2) MVC torque measured and (3) error model. The significance level (α value) was set at 0.05. Statistical analysis was performed with IBM SPSS Statistics software (version 20.0, Armonk, NY: IBM Corp.).

Results

All subjects completed the three months training protocol. The mean (± standard deviation, SD) physical

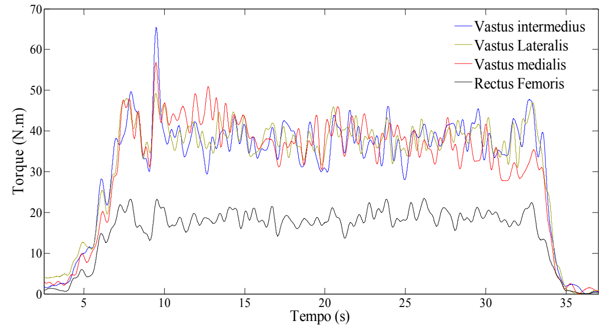

Figure 2: Individual QF component estimated torques.

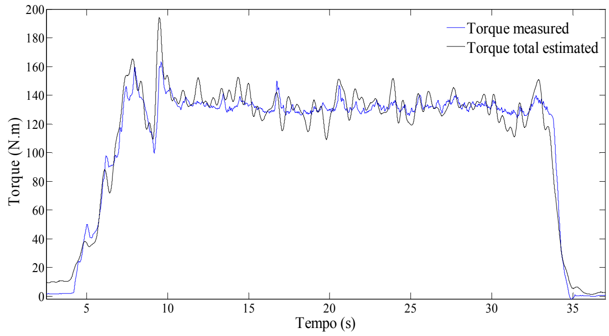

Figure 3: Measured (dynamometer) and estimated (EMG-Driven) knee torques.

characteristics of the subjects were as follows: age 17.33± 0.86 years; weight 70.57± 8.20 kg; height 1.80± 0.10m. The knee extension MVC torque was similar pre and post-training (pre: 334.55±24.75N.m; post: 330.55±26.43N.m; Z = - 0.29; P = 0.76). Table 1 show mean (±SD) of the means of MT, which presented no significant statistical differences (P > 0.36).

Table 1: Muscles thickness (mean ± SD**)** pre and post training.

Muscles	**Training**	
	pre (cm)	**post (cm)**
Vastus lateralis	2.38±0.09	2.37±0.10
Vastus intermedius	1.92±0.10	1.97±0.06
Vastus medialis	1.84±0.11	1.88±0.10
Rectus femoris	2.21±0.10	2.22±0.08

Figure 4 shows torque sharing patterns of the four QF components (pre and post-hypertrophy training). The pattern of individual contributions followed the sequence: RF < VM < VI < VL. Comparing the relative torque contribution intra-muscles, no significant statistical differences were observed (P > 0.31). The mean RMS model error was 13.11±1.97% before and 20.83±3.10% after training, with no significant statistical difference (Z= -1.48; P = 0.13).

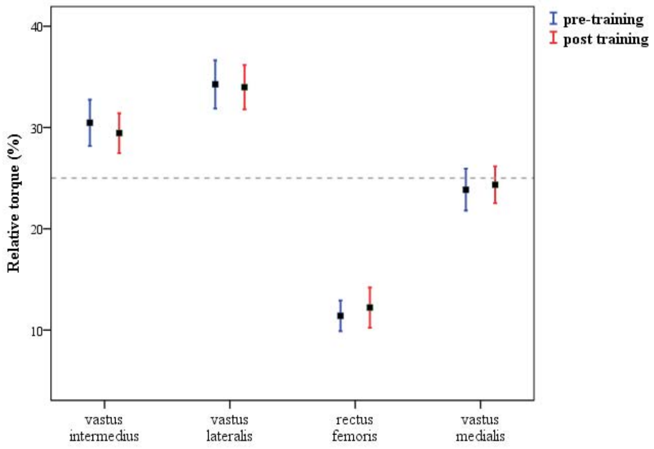

Figure 4: Relative estimated torque (mean ± SD) for each muscle, pre and post training.

Discussion

The protocol of hypertrophy was unable to induce significant maximum torque increase in the group of soccer players. The literature shows that combining strength training with jumps and sprints for periods of six weeks results in significant QF strength changes [15 – 16].

As the group was out of the competition season the results suggest that the protocol of hypertrophy was able, at least, to maintain subjects strength, given the similar MVC torque. But it was not sufficiently intense to promote hypertrophy, as the MT did not change.

Similar torque errors from EMG-Driven models can be found in the literature [17]. Individual relative QF contributions were similar to previous studies, which addressed similar protocols to ours, with 20 and 60% MVC steps [10 - 11].

Menegaldo and Oliveira [9] applied the same EMG-Driven approach strength-training protocol based on isokinetic exercises in four young males, by the period of 13 weeks. The authors found a similar pattern of individual muscle contributions for 20 and 60% MVC, pre and post-training, with an increase in the MVC torque of approximately 14.26% for non-athletes subjects.

Many daily life activities involve non-isometric knee tasks. A previous study has shown the contribution from each QF during walking using an EMG-Driven musculoskeletal model [8]. The VL muscle contributed approximately 45% during most of gait, followed by VI (~29%), VM (~26%) and RF (~5%). This pattern was similar to what we found in isometric contractions in the present study.

Zhang *et al.* [18], with intramuscular VI electrode, observed, during submaximal voluntary contraction, that VI contribution was significantly higher than all other QF components (39.6 to 51.8%). The VM contribution was smallest (9.5 to 12.2%), which disagree with our results. Differences in the EMG technique can explain the result, as EMG signals with wire electrodes are of greater amplitude, representing a small population of motor units [19].

The recording of deep muscles activation signals is a paradigm in neuromotor studies. The surface technique for VI proposed by Watanabe and Akima [13] seems to be a more physiological alternative compared to other protocols [9 – 11]. This protocol seems to be adequate to estimate the VI contribution to the knee extension torque, with an EMG-Driven model.

Some limitations of the present study must be pointed out. We consider that the global muscle activation was represented by the signal of the bipolar configuration of electrodes. In recent studies, selective regional muscle hypertrophy was observed after six weeks training period [20]. Different activation patterns are also found depending on the region of the muscle and level of force [21]. Considering different regions of hypertrophy within a muscle is a future question to address, using high density EMG.

The 40% MVC contraction was select to minimize co-contraction of antagonist muscles [22]. Others tasks and different levels of activation require further investigations.

Conclusion

The relative torque contributions among quadriceps muscle of soccer players showed that RF contributes less than the *vastii*. This pattern was maintained after strength training.

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