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Muscle mechanical properties of strength and endurance athletes and changes after one week of intensive training

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ABSTRACT

The study investigates whether tensiomyography (TMG) is sensitive to differentiate between strength and endurance athletes, and to monitor fatigue after either one week of intensive strength (ST) or endurance (END) training. Fourteen strength (24.1 ± 2.0 years) and eleven endurance athletes (25.5 ± 4.8 years) performed an intensive training period of 6 days of ST or END, respectively. ST and END groups completed specific performance tests as well as TMG measurements of maximal radial deformation of the muscle belly (Dm), deformation time between 10% and 90% Dm (Tc), rate of deformation development until 10% Dm (V10) and 90% Dm (V90) before (baseline), after training period (post1), and after 72 h of recovery (post2). Specific performance of both groups decreased from baseline to post1 ($P < 0.05$) and returned to baseline values at post2 ($P < 0.05$). The ST group showed higher countermovement jump ($P < 0.05$) and shorter Tc ($P < 0.05$) at baseline. After training, Dm, V10, and V90 were reduced in the ST ($P < 0.05$) while TMG changes were less pronounced in the END. TMG could be a useful tool to differentiate between strength and endurance athletes, and to monitor fatigue and recovery especially in strength training.

1. Introduction

Strength and endurance athletes are noticeably different from each other in physiological, morphological, and performance aspects (Costill et al., 1976; Hawley, 2009; Lattier et al., 2003). Albeit neural aspects (e.g., number and type of motor units recruited) play a significant role during the execution of different types of physical activity (Sale, 1987), muscle contractile properties (e.g., intrinsic muscular qualities) are key determinants of performance in both strength and endurance athletes (Costill et al., 1976; García-García et al., 2015; Lattier et al., 2003; Loturco et al., 2015). Accordingly, sprinters have a faster fiber type dominance, which favors a powerful muscle contraction in comparison with endurance runners, which in the other hand show higher proportion of slow fiber type (Costill et al., 1976).

There is evidence that the functional differences observed between athletes from sports of distinct physiological requirements are partly due to genetic endowment, as well as to training specific adaptations (Lattier et al., 2003). Endurance training stimulates several metabolic adaptations in trained muscle fibers, such as increased mitochondrial content, slower rate of glycogen utilization and greater reliance on fat oxidation. In contrast, resistance training promotes muscle hypertrophy and increases maximal strength (Hawley, 2009). Thus, it can be assumed that short-term intensive endurance and strength trainings lead to different muscular contractile responses.

In the applied field, there is an intense demand for sensitive and practical tools that would help to predict athletic performance in different types of sport (García-García et al., 2015; Loturco et al., 2015) and to understand the effects of intensive training periods (Kellmann and Günther, 2000). A large amount of the procedures commonly available are either invasive or motivation dependent, and might induce fatigue (Bosco et al., 1983; Breil et al., 2010; Fry et al., 1994). In this context, an alternative method, such as the tensiomyography (TMG), allows muscular function evaluation through the assessment of different mechanical properties.

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The TMG is a method based on the radial deformation of the muscle belly and the time it takes to occur during a twitch contraction evoked by electrical stimulation. It may provide an additional advantage in the applied field to detect between-group differences in cross-sectional comparisons (e.g., talent detection) and within-group changes in longitudinal assessments (e.g., after training and rest periods), as it allows a non-invasive evaluation of the contractile properties (Carrasco et al., 2011; de Paula Simola et al., 2015; Hunter et al., 2012) without producing additional fatigue, and examines muscle in isolation (García-García et al., 2015; Loturco et al., 2015). The TMG mechanical properties have been used to investigate the effects of different types of physical exercise, such as strength (de Paula Simola et al., 2015; García-Manso et al., 2012; Hunter et al., 2012) and endurance (García-Manso et al., 2011), besides estimating the fiber typer composition in skeletal muscle (Simunic et al., 2011). Nonetheless, information concerning differences in TMG mechanical properties of typical endurance and strength/power athletes is spare (Loturco et al., 2015). Furthermore, as far as we know, no study has examined the specific TMG response characteristics after intensive training periods.

Therefore, the purposes of the present study were: (1) to investigate whether the TMG mechanical properties are able to differentiate between strength/power and endurance athletes; and (2) to monitor the specific changes in contractile properties after either one week of intensive strength (ST) or endurance (END) training.

2. Methods

2.1. Participants

The ST group consisted of fourteen male athletes (age: 24.1 ± 2.0 years; weight: 78.9 ± 6.9 kg; height: 180.2 ± 5.1 cm; body mass index: 24.3 ± 1.8 kg m^{-2}; 1RM in the parallel squat exercise: 1.3 ± 0.2 kg BW^{-1}; CMJ: 44.1 ± 4.8 cm; $\dot{V}O_{2max}$: 57.4 ± 5.2 ml min kg^{-1}) experienced in strength training for at least three years with minimum of two strength training sessions per week. The inclusion criterion was the achievement of at least 120% of their body weight in 1RM in the parallel squat. The END group was composed of eleven well-trained male cyclists (age: 25.5 ± 4.8 years; weight: 69.7 ± 6.1 kg; height: 179.8 ± 6.0 cm; body mass index: 21.5 ± 1.4 kg m^{-2}; CMJ: 36.2 ± 4.4 cm; $\dot{V}O_{2max}$: 60.6 ± 6.6 ml min kg^{-1}; training amount, approx. 10,000 km yr^{-1}). As inclusion criterion, the participants had to accumulate at least 5000 km cycling training a year and competition experience at least at national level. The participants provided their written consent to participate in the study, which was approved by the local Ethics Committee of the Ruhr-University Bochum.

2.2. Design

The ST and END groups carried out a supervised and intensive training period of six days, which consisted of eleven training sessions of strength and endurance, respectively (Fig. 1). During the week before the training period, a health examination and one familiarization session were undertaken. Furthermore, in both groups, all baseline measurements including anthropometry, TMG, a countermovement jump test (CMJ), and an incremental cycling test to voluntary exhaustion to determine the maximal oxygen uptake $\left(\dot{V}O_{2max}\right)$ were performed.

Before (baseline) and after training weeks (post1), as well as after 72 h of recovery (post2), the specific functional capacities of both END and ST athletes were assessed in order to evaluate the influence of training periods on their respective fatigue status. For that, a 40-km cycling time trial (TT_{40}) and the CMJ were defined as the gold standard performance tests in the END and ST groups, respectively. At all measurement times, TMG measurements were followed by the specific gold standard performance tests.

Prior to the baseline measurements, participants were asked to refrain from strenuous exercise for at least 48 h, and to arrive at the laboratory in a fully recovered state. At the day before and at baseline test day, participants completed a food diary and were instructed to replicate their nutrition habits as closely as possible before the testing days. All the measurements were conducted at the same time of day (±1 h).

2.3. Training interventions

Both training periods were designed to induce fatigue via different neuromuscular and metabolic pathways and incorporate a broad range of strength and endurance methods used in the applied field. For all details about the training interventions, see Fig. 2.

2.3.1. ST training

The ST training consisted of accented lower-body completed by upper-body and core training. After a standardized 10 min warm-up, the following three different strength training protocols were applied: Multiple Sets (MS), Eccentric Overload (EO), and Flywheel (FW) (de Paula Simola et al., 2015).

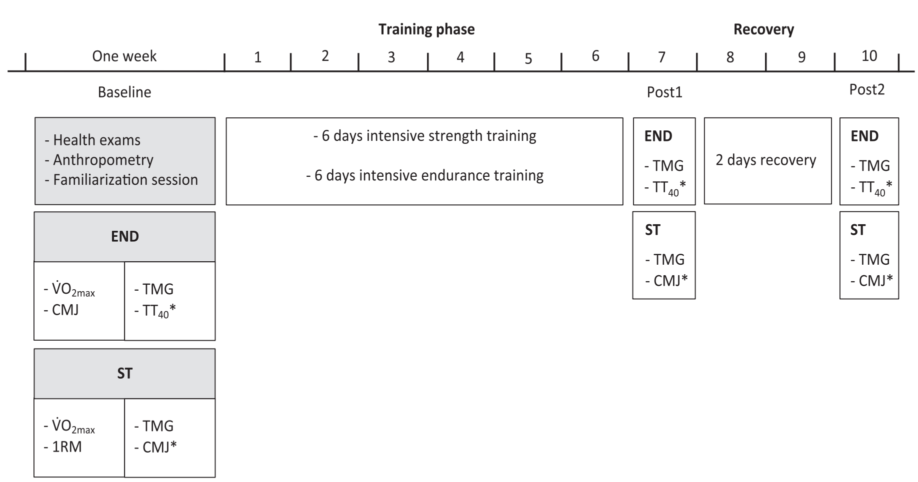

Fig. 1. Schematic illustration of the study design. ST = strength training group; END = endurance training group; 1RM = parallel squat one repetition maximum; $\dot{V}O_{2max}$ = maximal oxygen uptake; TMG = tensiomyography; CMJ = countermovement jump; TT_{40} = 40 km time trial. *gold standard performance test.