WEEKLY DEVELOPMENT OF FUNCTIONAL QUADRICEPS STRENGTH PARAMETERS DURING HIGH-INTENSITY RESISTANCE TRAINING

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The time course of muscular adaptation is unclear, especially for strength parameters measured by interpolated twitch technique, such as peak twitch torque, voluntary activation level and rate of torque development. Two male subjects participated in a longitudinal study over 11 weeks, with one pre-measurement, eight weeks of training and two weeks of detraining (rest). Resting twitch parameters decreased for both participants and only recovered to baseline level and above in the detraining phase. Voluntary quadriceps strength increased with training, with increasing activation level. The study shows the complexity of adaptation to intense strength training, being influenced by fatigue and individual factors and showing the need for a careful consideration of resistance training intensity in athletes prior to competition or scientific settings.

KEY WORDS: twitch interpolation, resting twitch torque, voluntary activation

INTRODUCTION: Investigating strength parameters is essential for identifying potentials in the training process. However, many studies only investigate few time points of measurement, i.e. a pre- and post-test values (Piirainen et al., 2011; Souza, Ugrinowitsch, Tricoli, Roschel, & Lowery, 2014). As voluntary factors influence most strength measurements, twitch interpolation can be used to measure net muscular strength (Behrens, Mau-Moeller, & Bruhn, 2014; Herbert & Gandevia, 1999), further described as twitch parameters. When investigating twitch parameters, usually only two time points of measurement are conducted on each subject (Behrens et al., 2014). Therefore the time course of the development of strength parameters remains unclear. In a study by Behrens, Mau-Moeller and Bruhn (2012), twitch parameters were determined pre and post a muscle-damage-inducing exercise as well as 24, 48 and 72 hours post test and seven days after the exercise. A fatigue dependent decrease in force and force production could be seen in all measured parameters with a recovery of strength in most parameters after seven days (Behrens et al., 2012). To our knowledge, no study exists regarding the development of twitch parameters in a longitudinal study with a detailed monitoring of these parameters. Thus, the purpose of this study was to investigate the development of twitch parameters during an intense longitudinal resistance training intervention.

METHODS: The study was designed as a longitudinal study with weekly measurements: a pre-measurement with one week of rest before training, eight weeks of intense strength training and a detraining phase of two weeks. Two active, healthy men volunteered to participate in this study (subject D and M; age: 24 and 23 years; weight: 83 and 65 kg; height: 186 and 175 cm; strength training experience: 0 and 1.5 years). Both participants gave written and informed consent to the experimental procedure, the study design was approved by the local ethics committee. At the beginning of each training session, isokinetic training (multi-joint leg press and single joint knee extension) was done in the Isomed 2000 (D&R Ferstl GmbH, Hemau, Germany) with concentric movement of 200 (weeks 1-4) up to 100 mm/s (weeks 7+8) and 100 (weeks 1-4) up to 200 mm/s (weeks 7+8) eccentric movement in the leg press. For the knee extension 45 to 90 °/s (concentric) and 90 to 45 °/s (weeks 1-4 and 7+8 respectively) were performed in eccentric contraction mode. The additional training consisted of a two day-split training program for the whole body with free weights and conventional training machines (Life Fitness Europe GmbH). Training intensity increased every two weeks for the isokinetic training, with increase of repetition number (from 8 to 10) after two weeks, and a reduction of concentric and an increase of eccentric contraction speed after 4 and 6 weeks. Additional training exercises were executed with the 8-10 repetition maximum (RM) with three sets and 1-2 min of inter-set recovery. Subjects increased load according to their RM for the additional training. A test-day consisted of measurements in the morning and a training session directly after the measurement. Resting twitch torques (RTT) were recorded as described by Mau-Moeller, Bruhn, Bader and Behrens (2014). Participants were seated on a dynamometer (Isomed 2000, D&R Ferstl GmbH, Hemau, Germany) with 80° hip-flexion and 80° knee-flexion (0° = fully extended). No warm up was conducted before measurement to prevent twitch potentiation. Transcutaneous electrical femoral nerve stimulation was used to analyse the stimulus response curve. EMG-signals of the M. vastus medialis were recorded using bipolar EMG Ambu Blue Sensor N electrodes with 2 cm diameter. Maximal m-wave was recorded and five doublet (10 ms inter stimulus rest) stimulations were applied to the nervus femoralis every six to seven seconds (randomized) with 150% of maximal m-wave with a constant-current stimulator (Digitimer DS7A, Herfordshire, UK). Signals were amplified (×2,500), band-pass filtered (10 – 450 Hz) and digitized with a sampling frequency of 2 kHz through an analogue-to-digital converter (DAQ Card TM -6024E; National Instruments, Austin, Texas, USA). Torque recordings were analysed with a custom built Matlab program to calculate peak twitch torque (PTT), twitch rate of torque development (tRTD) and twitch rate of torque relaxation (tRTR). Interpolated twitches were analysed as described by Behrens, Mau-Moeller and Bruhn (2014). In short, participants were seated in the same position as for RTT. Three maximal voluntary contractions were recorded with two minutes of rest between measurements. During contraction, a doublet stimulation was applied 1s after torque onset. Additionally a control twitch was applied 1-2 seconds (randomized) after torque was close to zero. Isometric maximum voluntary torque (iMVT), rate of torque development (RTD) and per cent of voluntary activation (%VA) were calculated according to Strojnik and Komi (1998). Besides the presented data in this abstract, muscle volume was determined with MRI-scans and ultrasound was used to determine fibre angles of m. vastus lateralis, medialis and rectus femoris. As only two subjects were examined, no statistical analysis were performed. For a better comparison, the data are presented as per cent changes to the baseline-value measured before training (week 0).

RESULTS: Both participants increased training volume per session linearly in the eight weeks of training. Unfortunately, participant M reported thigh pain in week 7, possibly influencing strength measurements.

Peak twitch torque decreased for both participants after the first week of training and stayed below baseline for participant D during the whole training and also at the end of the detraining phase (-6.7 %). Participant M could increase PTT in the detraining phase by 13.1 % compared to baseline. tRTD equally decreased after the first week of training and could only be increased by subject M after the detraining phase (5.3 %). Twitch rate of torque relaxation showed a similar time course as the other twitch parameters. In general, participant D had a higher decrease from baseline of PTT, tRTD and tRTR compared to subject M. Isometric maximal voluntary torque increased rapidly between the pre-test and baseline for both participants. With the level of voluntary activation increasing 0.7 % and 1.4 % for participant D and M respectively. The first four weeks of training were characterized by a slight decrease of iMVT and an increase of %VA. Then both participants increased their iMVT with slightly decreasing levels of %VA. Only participant M could increase RTD compared to baseline in the detraining phase, while participant D showed a decrease of RTD during the training phase with a slight increase after detraining. The time course of the analysed parameters can be seen in figure 1.

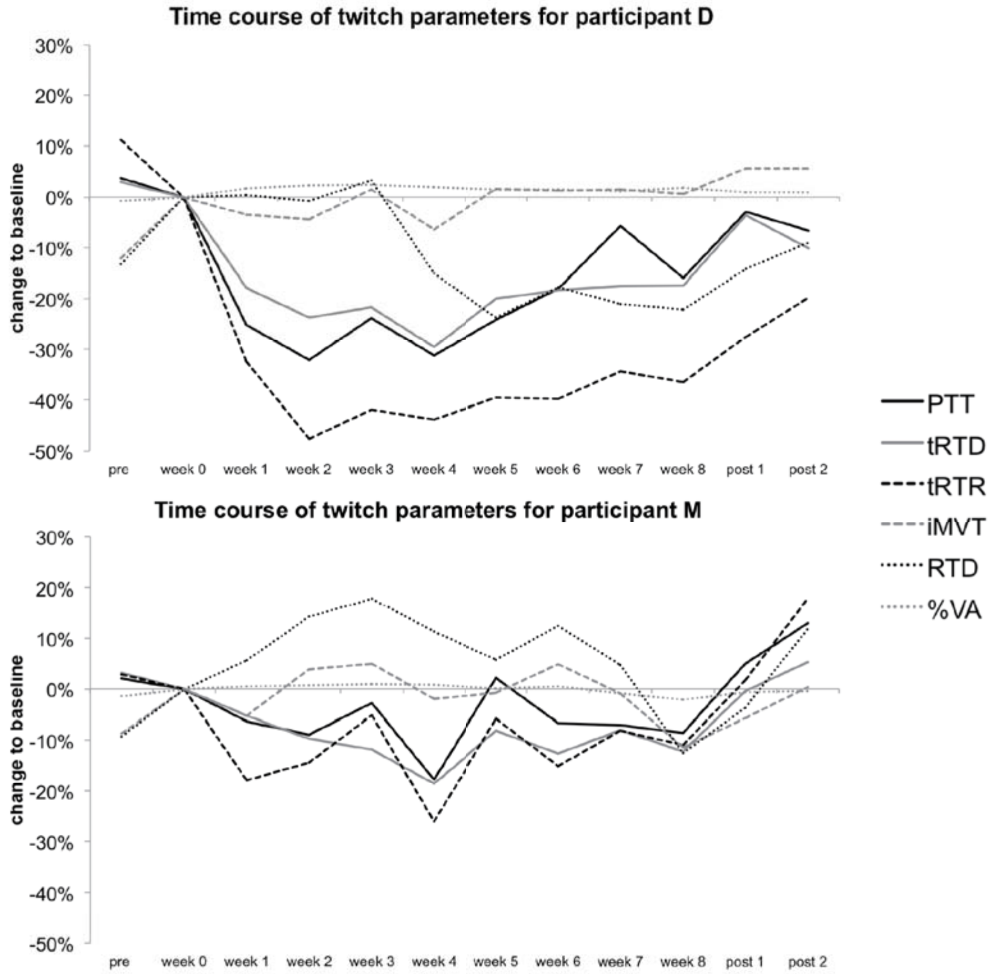

Figure 1: Time course of twitch parameters of both participants. All values are given as per cent changes to baseline (week 0). PTT= peak twitch torque, tRTD=twitch rate of torque development, tRTR= twitch rate of torque relaxation, iMVT=isometric voluntary torque, RTD=rate of torque development, %VA= voluntary activation level.

DISCUSSION: As shown in this study, the adaptation of twitch parameters to intensive strength training is complex. Many factors, i.e. training status, fatigue and other individual parameters seem to influence the time course of adaptation. As shown by Behrens et al. (2012), the influence of muscular damage reduces the force production in the twitch parameters for an extended period of time. For the two analysed participants, even after 8 weeks of training, some strength parameters were still reduced compared to baseline. However, in the present study, the participants were training three times a week with high intensity compared to one stress-protocol in the study by Behrens et al. (2012). For both participants, values only partly returned to or exceeded baseline values in the detraining phase. Participant D could not improve twitch parameters in the detraining compared to baseline, thus potentially showing the need for a longer recovery phase. The highest increase in voluntary strength gains can be seen from pre-test to baseline. During the training phase, both participants could increase voluntary strength, showing neuronal adaptation, as also confirmed by the increased voluntary activation level (%VA). Interestingly, %VA decreased after an initial increase in the first four weeks. Although %VA increased in the first four weeks, iMVT was reduced, especially for subject D, indicating a

loss of muscle contractile properties, also shown by the decrease in resting twitch torque parameters.
Participant M reported intense strength training before the beginning of the study. This could explain the lower decrease of twitch parameters with the start of the training phase when compared to participant D, who reported no resistance training experience.
As a limitation of the study, only two participants were examined due to the high costs of the accompanying measurements (MRI and ultrasound, data not presented here) and the detailed measurement procedure, therefore no general conclusions can be made based on this study. Further, the measured values may have been influenced by a remaining fatigue from the weekly training session two days before measurement. Thus, the actual positive training effects could not be measured completely with the presented setup. Additionally, nutrition and additional physical activities were not controlled for the participants.

CONCLUSION: As shown in this study, intense resistance training influences twitch parameters over a long time-course. Thus, the net ability of the muscle to produce force is reduced. Therefore, coaches should limit intense strength training close to competition. Especially for untrained athletes, recovery of muscular function can take longer than two weeks. For scientific purposes, a familiarisation phase must be included before start of the actual measurement, as we found the highest strength gains between pre and baseline measurement for the voluntary strength parameters. Further, time points of analysis of training effects must be chosen carefully, as fatiguing effects of the training phase can still be present in a detraining phase.

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