EFFECT OF MUSCLE ENERGY TECHNIQUE ON INCREASED CALF MUSCLE STIFFNESS AFTER ECCENTRIC EXERCISE IN ATHLETES

Aleksandra Kisilewicz¹, Marcin Urbaniak², Adam Kawczyński¹

¹ Department of Sport Sciences, University School of Physical Education in Wroclaw, Poland
² Department of Physical Education, University School of Physical Education in Wroclaw, Poland

Key words: eccentric exercise, muscle energy technique, muscle stiffness, calf muscle, myotonometry

Abstract:

Aim. The study aimed to assess changes in calf muscle stiffness after eccentric exercise (ECC), followed by the Muscle Energy Technique (MET). Our secondary objective was to evaluate the reliability of the novel MyotonPRO device for measurements of calf muscle stiffness in athletes.

Basic procedures. The study was conducted among 18 athletes from the University School of Physical Education in Wroclaw, practicing various sport disciplines. Stiffness measurements were obtained five times, bilaterally over the calf muscle: 1) test for the relative and absolute reliability, 2) re-test, 3) before the single bout of ECC, 4) after ECC but before MET, 5) after application of MET. The results were evaluated using the RM-ANOVA and Bonferroni post-hoc test. The $P$-value < 0.05 was considered significant.

Main Findings. Calf muscle measurements were obtained with the MyotonPRO device – reliable, hand-held and easy to use in field conditions. Myoton Technology provides an accurate and sensitive way for the objective and non-invasive digital palpation of soft tissues, which may find many applications in professional sports.

Results. The test-retest relative reliability was found to be almost perfect, with an ICC of 0.898 (95% Confidence Interval: form 0.851 to 0.930). The average SEM was 21.81 N/m and average MDC equated 60.42 N/m. There was a significant increase in right calf muscle stiffness after the single bout of eccentric exercise, compared to its baseline values ($P < 0.001$) and to the left leg ($P = 0.002$). There was a significant decrease in muscle stiffness after performing MET ($P = 0.001$). Initially and after MET, there were no differences between left and right legs ($P = 0.06$).

Conclusions. The study showed that single application of MET significantly restores the normal stiffness level increased after a single bout of ECC. It also proved MyotonPRO to be a reliable tool to assess calf muscle stiffness in athletes.

Introduction

Nowadays, in professional sport, nothing is random. Each athlete is under the supervision of a multidisciplinary team of experts, controlling all aspects of the training process [1]. There is a number of quantitative muscle parameters that allows to assess the psychophysiological state of an athlete [2]. Range of motion (ROM), as a common index of joint mobility, is generally divided in two conditions: active ROM, determined by
range of muscle contraction, and passive ROM, determined by an external force with the muscle remaining relaxed. ROM of active and passive dorsiflexion is determined by the elasticity of the calf muscle [3].

The calf muscle situated at the posterior side of the lower limb is composed of the soleus muscle, the medial and lateral heads of the gastrocnemius (composing the triceps surae muscle), and the tibialis posterior. These muscles insert onto the largest and strongest human tendon, known as the Achilles tendon [4]. The calf muscle contracts concentrically to induce the plantarflexion of the ankle joint and provides a raise in the centre of body mass. It leads to an action-reaction force against the ground for locomotion [5]. ROM of the ankle joint is related to performance in daily activities and sports [6]. Reduction of ROM dorsiflexion is reflected in a lower efficiency of walking and running and is related to several lower limb disorders, including Achilles tendinitis [7]. The decrease in ROM due to increased muscle stiffness can reduce the ability of the musculotendinous-unit to absorb impact and generate optimal force. Continuing sport performance during this stage of reduced impact absorption may increase the risk of injury [8].

Lack of flexibility and increased muscle stiffness has been primarily offered as an explanation for strain muscle injuries, which are often associated with eccentric overload of the musculotendinous-unit [9]. Eccentric contractions combine stretching and strengthening, wherein the musculotendinous-unit lengthens while the muscle is contracting [10]. As reported by many authors, eccentric exercise (ECC) is a successful treatment in tendon rehabilitation [11-13]. The rate of success for the ECC protocol in athletes ranges from 60% to 80% [14]. Moreover, lower metabolic cost allows to perform ECC at a relatively low central hemodynamic and metabolic demand, which increases their efficiency in physical therapy and athletic training settings [15]. However, as noted by Chaudhry et al. [16], the mechanisms underlying the observed effects remain unknown and need further investigation.

However, muscle tenderness due to palpation or soreness, as an effect of ECC, is very common among athletes. It is associated with exercise-induced damage of type I muscle fibres, called delayed onset muscle soreness (DOMS) [17]. An inflammatory response due to DOMS-related muscle damage leads to an increase in muscle stiffness and therefore, a reduction of ROM [18]. This explains the positive correlation between DOMS and the higher risk of strain injuries [19]. Therefore, the prevention of DOMS should be a great concern of coaches, trainers and therapists [20].

In general, muscle stretching is performed as a routine before training or a competition to increase flexibility and to prevent muscle damage [21]. It leads to elongation of the musculotendinous unit by increasing the distance of muscle origin and insertion [22]. In a systematic review by Thacker [23], it is clearly stated that stretching is recommended by all, athletes, coaches, trainers or physiotherapists, to both: prevent injury and enhance performance. The pre-contraction elongation, which involves the contraction of muscles before their stretching, is one of three major stretching techniques described in the literature [24]. This method, based on pre-contraction elongation, is also used in manual therapy and is called the muscle energy technique (MET). It can be successfully applied among athletes to lengthen muscles that lack flexibility [25]. Its greater effectiveness is based on the neuro-reflexive mechanisms of autogenic inhibition, which reduces agonist muscle tone after contraction to facilitate contraction of the antagonist, which facilitates muscle relaxation and lengthening [26].

Subjective manual palpation remains the most popular method to evaluate muscle tone. Objective measures require expensive technical equipment and complicated procedures, thus, they are not practical to use in the training process or sports medicine. Therefore, there is a need to introduce a new method for measuring muscle biomechanical parameters in athletes, including muscle stiffness [27]. The MyotonPRO device (Myoton AS, Tallinn, Estonia) proved to be a reliable tool in the assessment of muscle properties [28]. To the best of our knowledge, no study has investigated quantitative changes in muscle stiffness after the application of MET. Therefore, the aim of the current study was to determine the changes in calf muscle stiffness after eccentric exercise, followed by MET. We hypothesized that single application of MET will restore a normal level of calf muscle stiffness, increased after a bout of ECC, and thereby, will increase the dorsiflexion ROM. Our second objective was to evaluate the reliability of the novel MyotonPRO device for measurements of calf muscle stiffness in athletes.

Methods

Participants

The study involved 18 athletes representing various sports disciplines (mean ± SD; age: 22.0 ± 0.8; height: 1.71 ± 6.8 cm; mass: 72.1 ± 7.8; 8 females). Somatic measurements were taken with a mechanical balance beam scale (Seca Mechanical Column Scale with Measuring Rod Model 700). Participants were instructed to stand straight, with upper limbs along the trunk, barefoot. To be considered for inclusion in the study, participants had to fulfil the following criteria: 1. membership in AZS-AWF Wroclaw for at least a year; 2. regular participation at competitions and trainings, with at least 3 trainings per week (minimum 6 training hours per week). The main
criterion for exclusion was a recent injury to the lower limbs, which could affect the measured parameters of muscle stiffness or any pain during exercise performance. All participants provided informed consent, and the study was approved by the local ethics committee and conducted in accordance to the Declaration of Helsinki.

**Stiffness measurements**

Muscle stiffness is defined as the resistance of a soft tissue to contraction or an external force that deforms its initial shape [29]. Calf muscle stiffness was quantified using the damped oscillation method - the MyotonPRO device (Myoton AS, Tallinn, Estonia) (Fig.1).

The probe at the end of the device delivers a short mechanical impulse to the skin and below the tissues, directly under the probe (duration: 15 ms; force: 0.3 – 0.4 N). This generates natural oscillations within the muscle. The device records and calculates muscle stiffness within a few seconds after measurement.

For the evaluation of MyotonPRO device reliability to measure calf muscle stiffness, additional measurements were performed. First stiffness measurements were collected one day before (test) and the second (retest) on the day of research proper, by the same operator.

All measurements of muscle stiffness were obtained from 6 standardized points on both calf muscles: 1: right lateral gastrocnemius, 2: right soleus, 3: right medial gastrocnemius, 4: left medial gastrocnemius, 5: left soleus, 6: left lateral gastrocnemius (Fig. 2) [30].

To maintain consistency between participants, assessment points were drawn with a marker and measured by one operator. All outcomes were obtained with the participant lying in a prone position, with feet hanging off the table at an ankle angle of 90° and both calf muscles exposed.

**Eccentric exercise**

Afterwards, each participant performed a single bout of ECC. The ECC protocol consisted of 2 series with 15 heel drop repetitions and a 1 minute interval in-between. Beginning the exercise, each subject was instructed to stand at the edge of the step, on both feet, with the heels raised (Fig. 3).

Participants started the eccentric phase of exercise on the ball of the right foot, lowering the heel in a controlled manner for at least 3 seconds (Fig. 4).
The movement was performed, until full dorsiflexion was achieved (Fig. 5).

Subsequently, the left leg was used to assist in returning to the starting position before repeating the exercise (Fig. 6). All patients were given practice instructions on how to perform the ECC by the same physiotherapist, who later performed the MET stretching technique. The whole protocol lasted approximately 15 minutes.

Immediately after the ECC protocol was completed, a subsequent measurement of muscle stiffness for both calves was obtained.
Effect of muscle energy technique on increased...

Fig. 5. Right calf muscle during Muscle Energy Technique therapy

Fig. 6. Comparison of mean data of calf muscle stiffness in three measurements for both legs

* p < 0.05 was considered statistically significant
Muscle Energy Technique

After the second stiffness measurement, with about a 5-minute time interval from ECC, the right calf muscle was treated with the MET pre-contraction elongation technique and the contra-lateral side was the control. MET uses principles of neurophysiology with manual stretching techniques to lengthen shortened muscles and relax super active muscles [31]. When performing the technique, the subject is instructed to isometrically contract the agonist muscle from 20% to 25% of its maximal contraction strength. After the period of isometric contraction, the therapist actively uses a contrary force to lengthen the muscle that has previously contracted in order to obtain amplitude gain [32] (Fig.7). In the procedure, the MET therapist should apply sufficient resistance, compared to the force exerted on the isometric contraction of the patient. The contraction should be maintained for 10 seconds. It is the time required for the Golgi tendon organ be excited, and the muscular spindle be inhibited, and this way, the muscle can be led to a new range of movement [31]. The above procedure was repeated 3 times, and the whole MET treatment lasted for approximately 5 minutes.

At the end of the research procedure, the final stiffness measurement was obtained regarding the same 6 points of assessment.

Statistics

All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, IBM). The relative and absolute reliability of stiffness measurements were computed using Intraclass Correlation Coefficients (ICC), where the relative reliability was calculated by a 2-way fixed ICC (for absolute agreement). Additionally, the standard error of measurement (SEM) and minimum detectable change (MDC) were obtained. ICC values were evaluated according to Landis and Koch, where an ICC between 0.00 – 0.20 was considered as poor, 0.21 – 0.40 as fair, 0.41 – 0.60 as moderate, 0.61 – 0.80 as substantial and, 0.81 – 1.00 as almost perfect [33]. The SEM was calculated as: $SD \times \sqrt{1-ICC}$, where SD is the standard deviation of the scores from all subjects, and MDC as $SEM \times 1.96 \times \sqrt{2}$, respectively.

3 further stiffness measurements and 6 points of assessment were introduced as within subject factors in a full-factorial repeated measure analysis of variance (RM-ANOVA). The right (intervention) and left (control) side of calf muscle were included as the between subject effect in RM-ANOVA, with Bonferroni adjustment as the post hoc test. The normality of data distribution was checked using the Shapiro-Wilk test. In all the tests, a $P$-value < 0.05 was considered significant. Data are presented as mean ± standard error of the mean, unless otherwise stated.

Results

The test-retest relative reliability of stiffness was found to be almost perfect, with an ICC of 0.898 (95% Confidence Interval from 0.851 to 0.930). The average SEM was 21.81 N/m and average MDC equated 60.42 N/m. The ICC, SEM and MDC for each point of measurement are presented in a Table 1.

RM ANOVA revealed a significant increase in calf muscle stiffness of the right leg after the ECC protocol ($P < 0.001$). Right calf muscle stiffness (mean points 01 - 03) increased from 323.5 ± 62.9 N/m in first initial measurement, to 392.7 ± 104.1 N/m immediately after the ECC protocol, in the second measurement. There was also a significant decrease in right calf muscle stiffness after MET treatment ($P = 0.001$). Right calf muscle stiffness decreased to 361.8 ± 95.9 N/m in the third measurement. RM-ANOVA also showed a significant difference between right and left calf muscle stiffness in the second measurement ($P = 0.002$). There were no significant differences in calf muscle stiffness between the right and left leg for the first initial measurement or in the case of the third measurement ($P = 0.06$). Figure 8 shows the comparison between mean data of calf muscle stiffness before and after the ECC protocol and MET treatment, for the left and right leg.

Table 1. Intraclass correlation coefficients (ICC), standard error of measurement (SEM) and minimum detectable change (MDC) for calf muscle stiffness assessed over 10 measurement points.

<table>
<thead>
<tr>
<th>Points</th>
<th>ICC (95%CI)</th>
<th>SEM (N/m)</th>
<th>MDC (N/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P01</td>
<td>0.757 (0.335 - 0.910)</td>
<td>33.40</td>
<td>92.51</td>
</tr>
<tr>
<td>P02</td>
<td>0.440 (-0.323 - 0.779)</td>
<td>26.88</td>
<td>74.46</td>
</tr>
<tr>
<td>P03</td>
<td>0.808 (0.488 - 0.928)</td>
<td>15.85</td>
<td>43.90</td>
</tr>
<tr>
<td>P04</td>
<td>0.901 (0.741 - 0.963)</td>
<td>15.53</td>
<td>43.02</td>
</tr>
<tr>
<td>P05</td>
<td>0.831 (0.555 - 0.936)</td>
<td>25.96</td>
<td>71.92</td>
</tr>
<tr>
<td>P06</td>
<td>0.958 (0.887 - 0.984)</td>
<td>13.26</td>
<td>36.72</td>
</tr>
</tbody>
</table>
Effect of muscle energy technique on increased...
Conclusions

Our research showed that single application of the muscle energy technique restored a normal level of calf muscle stiffness increased after a single bout of eccentric exercise. However, this requires further investigation on a larger sample size and in relation to various sport disciplines, as an important issue in human biomechanics. Therefore, the MyotonPRO is an objective, reliable and easy to use in field conditions muscle stiffness measurement device, and may find many uses in professional sport.

References:

Effect of muscle energy technique on increased...