Changes in muscle stiffness as the effect of karate tournament fight

Authors' Contribution:
- A Study Design
- B Data Collection
- C Statistical Analysis
- D Manuscript Preparation
- E Funds Collection

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Abstract

Background & Study Aim: There is a number of research proving decrease of stiffness after different types of intensive aerobic exercise, such as marathon or triathlon. On the contrary, other authors confirmed that the stiffness increase, as a result of eccentric contractions related to the delayed onset of muscle soreness. To the best of our knowledge, no study has addressed the effect of karate fights on muscle stiffness, assessed by myotonometry. We hypothesised that a decrease in upper trapezius muscle stiffness among karate competitors in response to series of karate tournament fights.

Material & Methods: In part A (reliability of study), 15 right-handed non-trained males subjects (aged 20.7 ±1.2 years; height 174.6 ±6.1 cm; body mass 73.2 ±10.6 kg) volunteered to participate. In part B (experimental) 15 male karate competitors (age 24.7±4.5 years; height, 176.4 ±65.8 cm; weight, 72.3 ±5.4 kg;) volunteered to participate. We conducted a study composed of two measurements of upper trapezius muscle stiffness, directly before and immediately after tournament karate fight. The muscle stiffness was assessed using myotonometric measurements with the MyotonPRO device.

Results: Upper trapezius muscle stiffness in muscle belly sites decreased significantly from before fight (341.2 ±31.2 N/m) to after fight (302.3 ±34.7 N/m) ($p = 0.02$).

Conclusions: Two-minutes karate fight caused a significant decrease in muscle stiffness. Our findings could be an important asset for a trainer or other researchers investigating exercise-related changes in muscle stiffness.

Keywords: anaerobic exercise • martial arts • muscle diagnostics • muscle viscoelastic properties • myotonometry • trapezius muscle

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INTRODUCTION

Karate Shotokan is one of the oldest styles of karate. This Japanese martial art consists of three basic parts: kihon, kata and kumite. They represent respectively: basic techniques training, presentation of attack and defence skills and fight performance. The athlete's preparation for competition in karate is extremely complex. It includes all the components of the sports training process with technical, physical and psychological preparation. The fight requires a high dynamic of movements, with techniques often performed at maximal indicators [1]. A physical effort during karate fight requires high energy usage, attaining values about 3.5 times higher than subject's $VO2_{max.}$ In this type of exercises, the energy sources are essentially anaerobic, such as splitting of high energy phosphates [2]. Intense anaerobic exercise is associated with situations in which oxygen supply to muscle tissues is not fast enough, although blood flow is redistributed away from viscera toward working muscles. The high concentration of blood lactate, local hypoxia, tissue stretching and cytokine expression can produce temporary muscle damage [3].

The muscle stiffness reflects the resistance of the muscle to a contraction or an external force deforming its initial shape. Significantly increased value of stiffness leads to disorders motion sequence. It requires a greater effort from agonist's muscle to stretch a stiff antagonist [4]. Because of exercise-induced muscle damage, stiffness can increase in the days following exercise. Unaccustomed eccentric contraction imposes high mechanical force on muscles and tendons leading to cytoskeletal alterations. It contributes to impairments of neuromuscular function, which are expressed as a decrease of maximal muscle strength and motion range [5]. However, there is a lack of research with regard to measuring stiffness immediately after an intensive anaerobic exercise.

Muscle stiffness is linearly related to both active and passive muscle forces. Changes in stiffness values are associated with musculoskeletal and neurological conditions. There is a number of methods used to measure its changes noninvasively, e.g. electromyography (EMG) or shear wave elastography (SWE). The first one, although more popular, provides no information about passive force. Therefore, localised muscle stiffness can be quantified more accurate through the application of SWE [6].

There was a number of studies using EMG measurements to determine shoulder muscle activity. The upper trapezius muscle is regarded as producing an upward action on the shoulder girdle, being responsible for shoulder shrugging. Its activity is also present during adduction and abduction. However, despite the majority of descriptions, the middle part of the muscle is dominant during shrug and abduction movement, whereas the lower fibres are responsible for the adduction [7].

Myotonometry is representing a new technology to quantify mechanical properties of resting and contractile muscles. MyotonPRO is a reliable, valid, responsive and non-invasive device to quantify mechanical properties such as muscle stiffness, tone or elasticity [8]. A substantial advantage of MyotonPRO is that it can measure all three indicators simultaneously [9] and it is more sensitive to detect small changes than traditional measures [10]. Collected in a short time data, characterising mechanical properties of muscle are more objective [11]. Myotonometry have become increasingly popular in assessing viscoelastic properties of muscles.

There is a deficiency of research with regard to measuring stiffness immediately after physical work. Kawczyński et al. [12] estimated surface electromyogram (SEMG) changes within and between muscles of the torso and shoulder region, including trapezius muscle, during static endurance contraction in elite judokas. In another study, Adigozali et al. [13], measured the stiffness and thickness of the upper trapezius in rest and contraction states by ultrasonography (UT). To the best of our knowledge, no study has addressed the effect of karate fights on UT stiffness, assessed by myotonometry.

Viscoelastic characteristics of the skeletal muscle, as measured by the myotonometer, may provide new insights into muscle function and help to diagnose the stage of pathologic processes taking place in the muscles [14], this may provide information which may be applied in designing training load and injury prevention in different sports.

We hypothesised that a decrease in upper trapezius muscle stiffness among karate competitors in response to series of karate tournament fights.

Karate – a fighting method developed in Japan to defend oneself without the use of weapons by striking sensitive areas on an attacker's body with the hands, elbows, knees, or feet [33].

VO2max – the maximum rate of oxygen consumption as measured during incremental exercise, most typically on a motorised treadmill [34].

Anaerobic exercises – any short duration exercise that is powered primarily by metabolic pathways that do not use oxygen. Such pathways produce lactic acid, resulting in metabolic acidosis [35].

High Energy Phosphates – a chemical compound containing an easily hydrolysed phosphoric anhydride group [35].

Blood lactate – a lactic acid that appears in the blood as a result of anaerobic metabolism when oxygen delivery to the tissues is insufficient to support normal metabolic demands [35].

Hypoxia – deficiency in the amount of oxygen reaching body tissues [36].

Cytokine – a general term for non-antibody proteins released by a specific type of cell as part of the body's immune response [37].

Stiffness – biomechanical property of a muscle that characterises the resistance to a contraction or to an external force that deforms its initial shape [4].

Electromyography (EMG) – electrodiagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles [38].

Electrography – medical imaging modality that maps the elastic properties of soft tissue [39].

Ultrasonography – diagnostic imaging technique based on the application of ultrasound [40].

DOMS – delayed onset muscle soreness – muscle soreness that occurs 24-48 hours after exercise, especially after eccentric exercise. DOMS is characterised by mechanical muscle hyperalgesia, occasional resting pain, and altered motor control [41].

MATERIAL AND METHODS

Participants

In part A (reliability of study), 15 right-handed non-trained males subjects (aged 20.7 ±1.2 years; height 174.6 ±6.1 cm; body mass 73.2 ±10.6 kg, BMI 21.8 ±2.1 kg/m^2) volunteered to participate.

In part B (experimental) 15 male karate competitors (age 24.7±4.5 years; height, 176.4 ±65.8 cm; weight, 72.3 ±5.4 kg;) volunteered to participate. Competitors have been competing in Polish Championship of the Karate Shotokan. Informed consent was obtained from each subject. No participant reported any injuries.

The study was approved by ethics committee of University School of Physical Education in Wroclaw (Poland) and conducted in accordance with Declaration of Helsinki.

Measures

Handheld MyotonPRO device (MyotonPRO, Myoton Ltd, Estonia) was applied to measure upper trapezius muscle stiffness in karate competitors (1). Muscle stiffness (St; N/m) characterises the resistance of soft tissue to a contraction or external force and an ability to restore its initial shape (2). Five myotonometric measurements were performed at each tested point. During stiffness measurement subjects seated on a chair in a comfortable position with forearms supported on the desk. Subjects were instructed to fully relax their muscles during the measurements. Measurements were taken after the prefight warm-up. The calculation formula for the muscle stiffness:

$$S = a_{max} \times m_{probe}/\Delta l$$

where:

a – acceleration of the damped oscillation;

m_{probe} – a mass of the measurement mechanism (MyotonPRO, Myoton Ltd, Estonia);

Heart rate was measured immediately after fight using Polar heart rate monitor. It is not allowed to perform any measures during the fight;

blood lactate was assessed immediately after fight using Lactate Scout device.

PROCEDURES

Myotonometric measurements were taken directly before and after tournament fight. Each fight lasted 2 minutes. Whole research procedure was performed by the same person. MyotonPRO readings were performed over the upper subdivision of the trapezius muscle.

A wax pencil was used to mark the pressure point grid. The grid for measurements points recording was set by using C7-acromion distance "d" (mean: 19.5 ±1.5 cm) to compute the inter-distance between 15 points covering the upper trapezius muscle (Figure 1). Points 1, 3, 5, 10, and 15 were musculotendinous (MT) sites and points 2, 4, 6, 7, 8, 9, 11, 12, 13, and 14 corresponded to muscle belly (MB) sites [15].

Statistical Analysis

Part A: The relative and absolute reliability of stiffness and creep measurements were computed using intra-class correlation coefficients (ICC). The relative reliability was evaluated by calculating a 2-way fixed $ICC_{2,1}$ (for absolute agreement).

Part B: Collected stiffness values were introduced as within-subject factors in a full-factorial

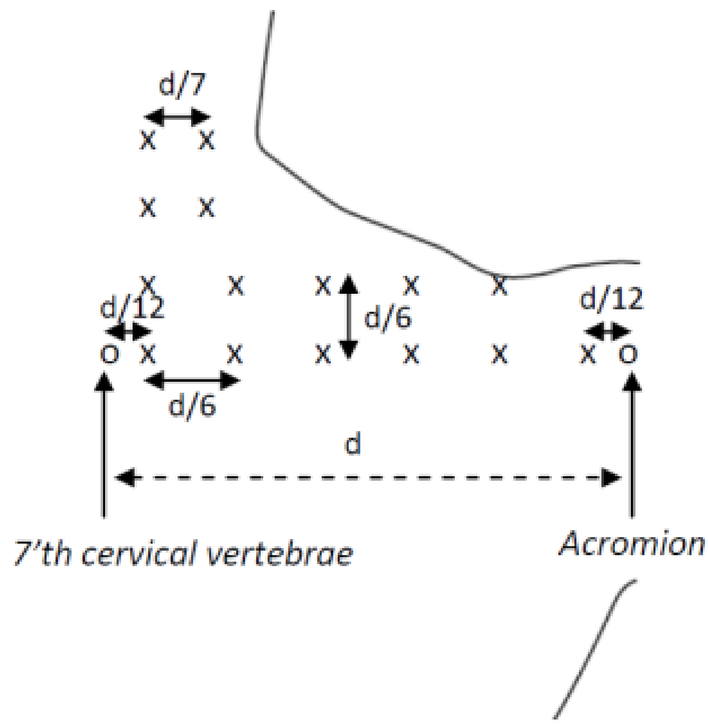

Figure 1. Schematic representation of myotometric measurements sites. Muscle stiffness was measured over 15 points located in the trapezius muscle.

repeated-measure analysis of variance (ANOVA). Bonferroni adjustment for multiple comparisons was used as post hoc test. The normality of the data distribution was checked by the Shapiro-Wilk test. In all tests, $p \leq 0.05$ was considered significant. The data are presented as mean and SEM in the text.

RESULTS

Part A – reliability

The test-retest relative reliability of stiffness was found to be almost perfect (ICC = 0.82) [16].

Part B – experimental

Average heart rate immediately after the fight was 178 ±6 beats/min. Blood lactate immediately after the fight was 11.2 ±0.7 mmol/l. Average muscle stiffness for muscle belly (MB) sites decreased significantly from before fight (341.2 ± 31.2 N/m) to after fight (302.3 ± 34.7 N/m) (p = 0.02). The average muscle stiffness for musculotendinous (MT) sites did not change significantly from before fight (421 ±60.3 N/m) to after fight (417.6 ± 56.7 N/m) (p = 0.3).

There was no significant difference between MT and MB sites average muscle stiffness before and after the fight (p = 0.4, p = 0.2 respectively).

DISCUSSION

The present study showed that tournament karate fight decreased stiffness in UT. The present study was first to investigate changes in UT stiffness as the effect of tournament karate fight. We found that UT stiffness decreased significantly specifically in muscle belly sites. Increase in muscle temperature may result in a reduction of stiffness [17-19].

Latash and Zatsiorsky [20] reported that tendons act as mechanical buffers protecting muscle fibres from damage during eccentric contractions. They gather stiffness to protect muscle fibres. In another study, there is a consensus that tendons act as a mechanical buffer protect muscles from possible damage associated with rapid active stretching [21-23]. This is in line with our study which showed that stiffness for MB sites decreased, while stiffness for MT remains unchanged.

Delayed onset of muscle soreness (DOMS) is a result of eccentric contraction, where muscles are forcibly lengthened, and the muscle acts as a brake to control the motion of the body [24]. The differences in the level of muscle damage for muscle belly and myotendinous part could explain our results. Weerakkody et al. [25] found that even in one muscle suffering from DOMS the decrease of pain threshold was not distributed evenly, suggesting that the level of damage underlying the soreness were discrete and separated by regions of the uninjured muscle. Research confirmed that DOMS causes muscle damage. This triggers adaptation of tissue, to protect against further injury during subsequent eccentric exercise [26].

Other researchers also investigated the changes in mechanical properties of muscles after exercise. Lacourpaille et al. [4] used shear wave elastography (SWE) to quantify the time-course changes in muscle shear elastic modulus. According to their results, the elasticity of examined muscle significantly increased after the eccentric exercise. These studies are consistent with the assumptions of previous authors relating to DOMS. The same measuring technique was also used by Hug et al. [6] to quantify the localised muscle stiffness. Janecki et al. [27] described this indicator, as a length-tension dependence in relaxed muscle. They investigated changes in passive muscle stiffness after eccentric exercise. Their findings were in agreement with the previous research, confirming the increase of measured indicator as a result of eccentric exercise. Consequently, their study seems to argue with our assumptions and results. As a further matter, they also used Myoton device for measuring changes in muscle stiffness. Thus, the main difference seems to be associated the type of exercise preceding the measurement.

Heterogeneous changes in muscle stiffness for MB and MT sites are in line with other researchers investigating different muscle properties. Baker et al. [28] reported that muscle damage after eccentric exercise is not distributed uniformly. Moreover, the same authors proved, that the pressure pain tolerance of myotendinous sites is lower than that of the muscle belly. A similar conclusion was also presented by Nie et al. [29] according to shoulder muscles. It can be explained by the different role of individual muscle matrix components and spatial interaction after exercise for trapezius muscle [15]. Our findings of heterogeneous changes in MB and MT stiffness can also refer to a different thickness and blood supply in particular regions of examined muscle [13].

Our results are also in line with other authors [30-32] who have proved that muscle belly stiffness decreases after physical activity, although with the use of different measuring equipment such as elastography or tension-myography.

There are certain limitations for presented research which need to be considered. The study did not include a control group. Greater sample size is needed to permit more generalised interpretation of results.

CONCLUSIONS

Our study demonstrated that physical activity during two-minute karate fight decreases the stiffness of upper trapezius muscle. We also reported heterogeneous changes of stiffness for myotendinous and muscle belly sites, which is in line with recent studies. Obtained results could set the way for future research to determine the impact of stiffness measurements in the sport. These findings can be important information for injuries prevention and training loads programming as the technique can be applied to assess acute changes in viscoelastic muscle properties and avoid muscle overloading during karate training and tournament.

HIGHLIGHTS

We would like to emphasise that our findings contribute to a better understanding of muscle stiffness and show the usefulness of myotonometry for monitoring the physical condition of muscles during training or competition.

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