Effects of lower fatigue protocols on motor neuron excitability in Korea National Team Taekwondo athletes

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

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Abstract

Background and Study Aim: Muscle fatigue and Golgi tendon organ laxity, which also, increases the threshold of muscle spindle discharge and disturbs afferent feedback. The purpose of this study was the effects of fatigue in lower extremities (quadriceps and hamstring) on H-reflex, M-wave, and Hmax/Mmax ratio changes in Korea National Team Taekwondo athletes.

Material and Methods: Twelve (7 male, 5 female) Korea National Team Taekwondo athletes were investigated. Participants completed 25 repetitions and 50 repetitions of fatigue protocol by using isokinetic dynamometer. The measured values of H-reflex and M-wave were collected simultaneously by electrical stimulation, and the signals were amplified by the signal converter.

Results: Paired t-test showed that the 25 fatigue protocol and 50 fatigue protocol in minimum of knee extension and flexion showed a significant difference. However, no significant difference in 25 fatigue protocol and 50 fatigue protocol in a maximum of knee extension and flexion. The changes of Hmax, Mmax and Hmax/Mmax ratio. There were no significant differences in Hmax, Mmax and Hmax/Mmax ratio.

Conclusions: Our fatigue protocols model increased locally fatigued in the quadriceps and hamstring. However, Hmax and Hmax/Mmax ratio of the soleus muscles tend to decrease after the fatigue protocol but did not change.

Keywords: electrical stimulation • H-reflex • HRmax • M-wave • signal converter

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Taekwondo – is a combative sport and was developed during the 1940s and 1950s by Korean martial artists.

Fatigue – *noun* very great tiredness [37].

Threshold – *noun* **1.** the point at which something starts, e.g. where something can be perceived by the body or where a drug starts to have an effect **2.** the point at which a sensation is strong enough to be sensed by the sensory nerves [37].

Tendon – *noun* a sinew or strand of strong connective tissue that attaches a muscle to bone [37].

Muscle spindle – *noun* any of the sensory receptors that lie along striated muscle fibres [37].

Electrical stimulation – *noun* same as **TENS** [37].

Conduction – *noun* the process of passing heat, sound or nervous impulses from one part of the body to another [37].

Performance – *noun* the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [37].

Crossover study – in a randomized clinical trial, the subjects are randomly assigned to different arms of the study which receive different treatments.

INTRODUCTION

Taekwondo competitions are organized movement sequences consisting of blocking, punching and kicking techniques by using the hands and feet without missing [1]. During taekwondo competition, the athlete performs a substantial number of kicking movements, which causes fatigue [2]. Besides, taekwondo competitions are conducted at an average of 85% to 95% intensity of maximal heart rate (HRmax) from the 1st to 3rd round [3]. This may be categorized as the high-intensity sport as considered by Borg & Linderholm [4], who classified over 80% of HRmax as high-intensity exercise and Brouha & Harrington [5] classified 162 to 182 bpm as high-intensity exercise.

High intensity exercise and activity increase muscle fatigue and Golgi tendon organ laxity which also, increases the threshold of muscle spindle discharge and disturbs afferent feedback, thus it affects the proprioception and motor sense of the joint [6-8]. Moreover, the fatigued condition was occurring within the muscle, with slowed conduction of feedback systems (i,e. nerve conduction velocity) and reduced muscle contraction rates, as the result negative effects in providing joint stability within the motor sensor system [9].

The Hoffmann-reflex (H-reflex) is one of the types of late response in electrodiagnosis, which was first described by Hoffmann in 1918 [10]. The afferent (sensory) portion of the H-reflex begins at the point of electric stimulation and results in action potentials travelling along afferent fibres until they reach and synapse on alpha motor neurons [11]. H-reflex measurements can be used to evaluate various nervous system responses [12, 13], assessment of training [14, 15], and to assess musculoskeletal injuries [16-19]. And the H-reflex has been an excellent tool in determining magnitude and distribution of spindle input to a motor neuron pool, travelling directly toward the muscle and recorded as the muscle response (M-wave) [20].

Especially, taekwondo athletes proprioception is significant for performance. Therefore, the purpose of this study was the effects of fatigue in lower extremities (quadriceps and hamstring) on H-reflex, M-wave, and Hmax/Mmax ratio changes in Korea national taekwondo athletes.

MATERIAL AND METHODS

Participants

Twelve (7 male, 5 female) Korea National Team Taekwondo athletes were investigated (Table 1). All subjects who agreed to participate in the study had the study explained to them to ensure a complete understanding of its purpose and methods, in accordance with the ethical principles of the Declaration of Helsinki. The subjects also signed an informed consent form before participation.

The study received approval from the Korea Institute of Sport Science (IRB KISS-1808-038-01) before participant recruitment began.

Procedures

All participants conducted a measure of H-reflex and M-wave at two times for after fatigue protocols. A randomized, repeated-measures crossover design was utilized for this study, where each participant completed 2 fatigue protocols: (1) rest and 25 repetitions and (2) rest and 50 repetitions. During the first visit to the laboratory, participants completed the informed consent form and measurement of body composition. And rest condition for H-reflex and M-wave were measured after, then immediately after 25 repetitions, H-reflex and M-wave

Table 1. The characteristic of the subjects.

Variable	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Total (n = 12)	23.33 ±3.14	179.80 ±8.02	71.51 ±13.64	21.96 ±2.69
Male (n = 7)	23.28 ±2.11	183.87 ±5.75	77.64 ±13.20	22.86 ±3.00
Female (n = 5)	23.40 ±3.93	174.10 ±6.29	62.92 ±6.22	20.70 ±0.83

were measured. In the second visit, rest condition H-reflex and M-wave were measured and then immediately after 50 repetitions, H-reflex and M-wave measured.

H-reflex and M-wave were measured immediately after the fatigue protocol was performed.

Measurements of Hoffmann-reflex (H-reflex) and muscle response (M-wave)

The subjects' skin was first carefully prepared by shaving, abrading and cleaning with alcohol. Bipolar silver chloride (Ag/AgCL) surface electrodes (Kendall Medi-TraceTM, Mansfield, MA, USA) that were 2 cm in diameter with an inter-electrode distance (centre to centre) of 2 cm were placed on the soleus muscle along the mid-dorsal line of the leg, ~5 cm below the insertion of the two heads of the gastrocnemius on the Achilles tendon. The reference electrode was placed on the medial malleolus. The EMG signal was amplified with a bandwidth frequency ranging from 5 Hz to 1 kHz (Gain = 1000). The EMG signals were sampled at 2 kHz with the Biopac acquisition system (MP35; BIOPAC, Goleta, CA, USA) and stored with commercially available software (BIOPAC student Lab Pro; Biopac system Inc.) for analysis.

H-reflexes and M-waves were evoked by percutaneous stimulation of the posterior tibial nerve in the popliteal fossa with a single rectangular pulse (1 ms) automatically delivered by a constant current stimulator (Model DS7 AH; Digitimer, Hertfordshire, UK). The self-adhesive cathode (1-cm diameter, Ag/AgCl) was placed in the popliteal fossa and the anode (5 × 10 cm, Medicompex SA, Ecublens, Switzerland) on the surface of the soleus muscle. The optimum cathode position was located with a hand-held cathode ball (0.5-cm diameter). Once determined, the cathode electrode was fixed to this site without pressure (NP condition), with manual pressure (MP condition) or with tape pressure (TP condition). This procedure, performed to find the optimal stimulation site, was repeated at the beginning of each experimental session.

Fatigue protocol

Participants completed 25 repetitions and 50 repetitions of fatigue protocol by using isokinetic dynamometer (Humac norm, CSMI, Stoughton, MA, USA). The straps were crossed over the trunk, pelvis, and the dominant thigh by using Velcro; the dynamometer axis of rotation was aligned to the external femoral condyle of the knee; the range of movement was set at 0° to 100° of flexion and extension. In order to familiarize the subjects, before starting the test, two series of five repetitions were done at the same speed of 240°/s as during the protocols.

Data collection

The measured values of H-reflex and M-wave were collected simultaneously by electrical stimulation, and the signal converter amplified the signals. The mean peak-to-peak amplitudes of the soleus Hmax and Mmax were calculated over recordings for each experimental condition. The Hmax/Mmax ratio was calculated as a percentage of Mmax. Also, measured maximum and minimum for knee extension and flexion peak torque by using an isokinetic dynamometer. The data were normalized to the percentage of participants' body weight.

Statistical Analysis

The SPSS statistical package version 23.0 for Windows (SPSS, Inc., Chicago, IL, USA) was used to perform all statistical evaluations. For the percentage of maximum and minimum knee extension and flexion, peak torque data were further analyzed for significant difference between the fatigue protocols (25 rep. and 50 rep) using a paired t-test. And Two-way analysis of variance (ANOVA) was used to determine interaction (time × type) effects for all outcome variables. Statistical significance was accepted at the 0.05 level. All variables are presented as the means ± standard deviations.

RESULTS

Paired t-test showed that the 25 fatigue protocol and 50 fatigue protocol in a minimum of knee extension and flexion showed a significant difference (Figure 1). However, no significant difference in 25 fatigue protocol and 50 fatigue protocol in a maximum of knee extension and flexion was present (Figure 2). There were no significant differences in Hmax, Mmax and Hmax/Mmax ratio (Table 2).

DISCUSSION

Taekwondo competitions require repeated movement such as punching and kicking for achieving scores during bouts of 3 rounds of 2 minutes. As we have known that repetitive movements lead to fatigue, which is to reduce the speed of

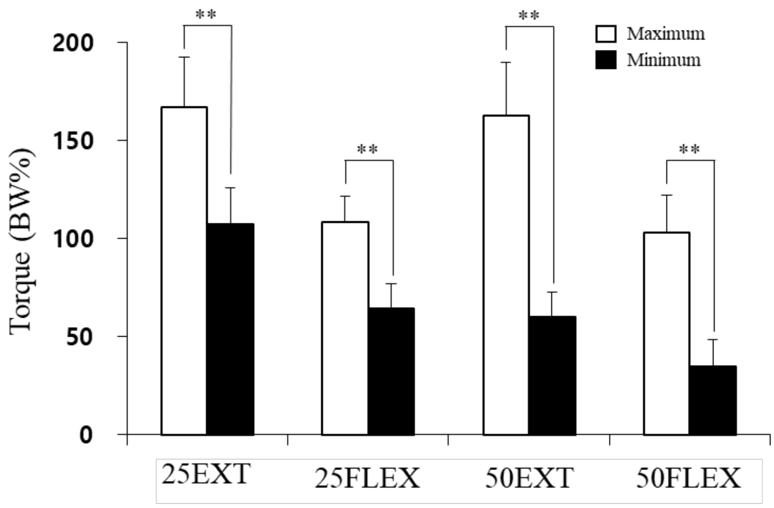

Figure 1. Comparison of knee extension and flexion peak torque between maximum and minimum.

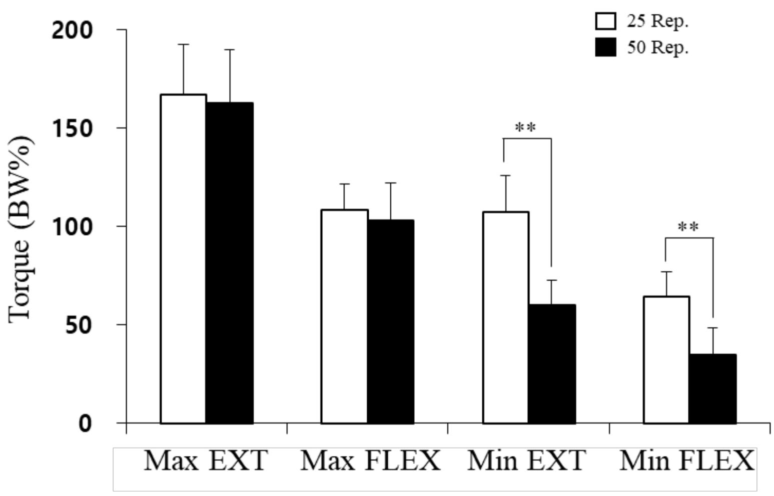

Figure 2. Comparison of knee extension and flexion peak torque between fatigue protocols.

movement [21, 22]. Also, it has been reported that muscle fatigue has a negative effect on the ability to regulate balance by decreasing the efficiency of the neuromuscular control mechanism [23]. Proprioception detects the movement and position (posture) of the body and transmits to the central nervous system [24]. If the role of proprioception is lost, the problem of maintaining the stability of the joint occurs and exercise performance is reduced [25]. Previous studies reported that increased the errors after both eccentric and concentric exercise that effort required to support the leg after fatigue from exercise was responsible for the errors [26]. And fatigue from exercise impairs judgements of muscle force and that subjects are matching efforts rather than actual force levels [27]. The H and the M values are represented as Hmax/Mmax ratio, a method of normalization that allows comparison between subjects, which is expressed as the ratio of the total motor neurons that can be activated [11]. The larger the values are the more nerves can be mobilized [28]. Motor neuron pool excitability is defined as the number of motor neurons capable of responding to excitatory stimuli within a given motor neuron [29]. H-reflex is used to measure the excitability of motor neurons located within the targeted motor neurons [30]. The present study is to investigate the effects of fatigue in the lower extremities (quadriceps and hamstring) on H-reflex, M-wave, and Hmax/Mmax ratio changes in Korea national Taekwondo athletes.

Table 2. Changes in Hmax, Mmax, and Hmax/Mmax according to fatigue protocols.

Variable	Type	Pre	Post	f-value (time × type)	p-value (time × type)
H_{max} (mV)	25 Rep. 50 Rep.	2.54 ±1.36 2.60 ±1.71	2.47 ±1.32 2.39 ±1.87	0.244	0.626
M_{max} (mV)	25 Rep. 50 Rep.	6.76 ±3.19 7.74 ± 3.90	7.05 ±3.26 7.93 ±3.86	0.135	0.717
H_{max}/M_{max}	25 Rep. 50 Rep.	46.1 ±29.5 43.2 ±29.5	42.7 ±26.8 39.1 ±30.1	0.031	0.862

We used isokinetic equipment to induce locally fatigued of quadriceps and hamstring and to measure H-reflex and M-wave in the soleus muscle. The main findings of this study are that there are significant differences in maximum and minimum for knee extension and flexion peak torque of both fatigue protocols (25 rep. and 50 rep). On the other hand, it was determined that both fatigue protocols were proven to cause locally fatigued in the quadriceps and hamstring. However no significant difference in Hmax, Mmax and Hmax/Mmax ratio.

Muscle and joint fatigue reduces the activity of the ligaments, muscles spindle, and tendon organs and increases laxity [31]. The increase in soft tissue laxity due to fatigue has been reported to have a negative effect on the change of the proprioception sensation and especially, it affects the athletes' performance [32]. In this study, 25 fatigue protocol and 50 fatigue protocol in a minimum of knee extension and flexion showed a significant difference. This result shows that the two fatigue protocols caused local fatigued in the lower extremities (quadriceps and hamstring). However, the Hmax and Hmax/Mmax ratio of the soleus muscles tend to decreased after the fatigue protocol but were not statistically significant. It was found that the local fatigued induced in lower extremities by the comparison of knee extension and flexion torque values after fatigue protocols. However, the local fatigued of the quadriceps and hamstring did not affect the rate of mobilization of motor neurons in the soleus muscles.

Recently some previous studies on the relationship between fatigue and H-reflex suggested conflicting results according to the fatigue protocols. Armstrong et al. [33] reported that significant in H-reflex after Wingate test fatigue protocol in eight college students. Using different fatigue protocols, Trimble et al. [34] reported that performed periodic concentric-eccentric movement of the triceps surae muscle for 10 minutes, followed by H-reflex. As a result, H-reflex was to show an initial decrease. Boerio et al. [35] observed a deceased in the maximum spontaneous contraction torque of the plantar flexor muscles through electromyographic stimulation but showed no significant change in the H-reflex of the soleus muscle. In this study, using fatigue of thigh muscle of taekwondo athletes has the simmer fatigue protocols as the study of Armstrong et al. [33], but the results show that, unlike the study using Wingate test, fatigue caused by repetitive kicking using isokinetic equipment did not affect H-reflex and M-wave changes.

Although the above limitations urge caution in interpreting the findings of the work, this study indicates that even if subjects are national taekwondo athletes, the sample size was small, and further larger populations studies required to confirm the relationships observed in this study. Also, H-reflex studies will be needed in the future because of the lack of previous studies on the effect of H-reflex on local muscle fatigue.

CONCLUSIONS

Our fatigue protocols model increased locally fatigued in the quadriceps and hamstring. However, Hmax and Hmax/Mmax ratio of the soleus muscles tend to decrease after the fatigue protocol but did not change. Local fatigued of the quadriceps and hamstring may not directly alter the rate of mobilization of motor neurons in the soleus muscles. H-reflex pathway is strongly involved in chronic adjustments in response to endurance training, contributing to enhancing resistance to fatigue [36]. Thus, fatigue can affect athletes, especially taekwondo athletes, and appropriate recovery is needed to prevent injury.

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