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Perspectives for improvement of karate stance performance on the basis of electromyogram analysis

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Key words: Kyokushinkai karate, fudo dachi, kokutsu dachi

Abstract
Background. The performance of exercises could be significantly improved on the basis of a detailed analysis of muscle activity, which can be studied by registering its electrical activity. We aimed to examine the activity of some of the muscles of karatekas during the performance of Kyokushinkai karate stances.
Methods. Participants – 16 highly qualified (1 dan, 12-17 years' experience) male Kyokushinkai karate athletes, aged 18-25. Surface electromyogram (sEMG) was recorded during the basic Fudo dachi and Kokutsu dachi stances. The electrical activity of m. gluteus maximus, m. rectus femoris, m. biceps femoris, m. semitendinosus, m. gasterocnemius (caput lateralis), m. tibialis anterior was registered.
Results. We found low (up to 38% of the maximum) levels and right-left symmetry of the mean amplitude and frequency of sEMG in the case of Fudo dachi. This is in good agreement with the proper technique for performing the stance. However, the electrical activity of some leg flexors (up to 23%) and foot flexors (up to 26%) was unexpectedly high, which may speed up the development of fatigue. We found higher levels of sEMG indices in the left ankle dorsiflexors and left knee flexors and extensors, as well as the right ankle plantarflexors in the Kokutsu dachi as compared to the Fudo dachi stance. The highest level of sEMG amplitude was registered for the m. gasterocnemius d. (up to 58%) and m. tibialis anterior s. (up 46% to). Bilateral asymmetry in the sEMG indexes was found for the majority of the leg muscles, except m. semitendinosus. Unexpectedly high-level activity in the ankle plantarflexor in the front leg was found.
Conclusions. The comparison of the sEMG data with the descriptions of the stance performance allowed us to elaborate the models of muscle activity during exercises and to assume some peculiarities in the technique of the performance of the stances.

Introduction

The studies, aimed at improving the technique of performing competitive exercises in *karate*, have received increased attention in recent years. One of the modern trends in these studies is the biomechanical [Rinaldi *et al*. 2018; Blaszczyszyn *et al*. 2019] and electromyographic analysis of exercises [Witte *et al*. 2005; VencesBrito *et al*. 2011]. Using biomechanical analysis, researchers try to create an external model of movement, while electromyographic analysis allows them to create an internal model associated with the activation of some muscles of athletes during the performance of the competitive exercises. Despite the significant number of publications devoted to the analysis of the performance of strikes in *karate* [Rinaldi *et al*. 2018; Jemili *et al*. 2017; Hariri, Sadeghi 2018; Błaszczyszyn *et al*. 2019], much less attention is paid to the study of stances. At the same time, according to the literature sources, the basic *karate* training clearly sets requirements for the correctness of the stances, because if they are performed incorrectly, attack and defense techniques become ineffective [Oyama 2004]. In addition, some authors [Cook 1985; Oyama 2004] indicate the possible occurrence of

injuries, in particular of the knee joints, in the case of improper performance of the stances.

The electromyographic analysis of the stances will determine the model characteristics of muscle activity during their performance and eliminate possible errors that may result in deterioration of exercise technique, the rapid development of fatigue or even cause health disorders in athletes. In a large number of recent studies, much attention is paid to the analysis of the movement of individual parts of the body with the parallel recording of the electrical activity of the muscles of *karate* athletes [Rinaldi *et al*. 2018; Jemili *et al*. 2017; Camomilla *et al*. 2009; Hariri, Sadeghi 2018; VencesBrito *et al*. 2011]. The numerous studies of karate striking techniques, in particular Mawashi-Geri [Hariri, Sadeghi 2018], Guiaku-Zuki [Jemili *et al*. 2017; Witte *et al*. 2005], Hiza-Mawashi-Geri [Jemili *et al*. 2017], Junzuki [Rinaldi *et al*. 2018], and *kata* [Camomilla *et al*. 2009] have been performed. By comparing the exercise performance of experienced athletes and beginners [Valdes Badilla 2018; Zago 2015; Blaszczyszyn *et al*. 2019], researchers try to describe the mechanisms of improving the motor skills in martial arts. Some attempts have been made to describe the model characteristics of changes in the electrical activity of muscles that results in optimal movement parameters. Much less attention is paid to the analysis of the performance of the stances, although Masatoshi Nakayama [Nakayama, Kauz 2012] notes that "strong, solid, correct and perfectly performed techniques are performed only on the basis of a strong and stable position (stance)" According to this author, in the absence of sufficient balance and stability, attack and defense techniques become ineffective.

In the description of the proper technique of stances performance, much attention is paid not only to the position of the limbs, including legs but also to the level of the muscles tension. Thus, describing the Zenkutsu dachi stance, some authors [Nakayama, Kauz 2012] note that there are important differences between the preparatory stance for the strike performance and the same stance at the time of the striking. In the first case, the knee of the front leg should be bent, the thigh muscles and the calf of both legs are relaxed, but at the time of the strike performance, the leg muscles should be tense.

Emphasis is also placed on the distribution of body weight while holding the stances. Thus, when performing the Zenkutsu dachi stance, the front leg should take 60%, and the back leg – 40% of the body weight. In the Kokutsu dachi stance, this ratio should be 30% to 70% (front/back leg) of body weight [Nakayama 1987]. To date, some research intended to test the weight distribution while performing the stances [Aguiar de Souza *et al*. 2015], while other authors revealed the correlations between the right and left limb in balancing ground reaction forces in the case of athletes and students in the process of maintaining an upright body position [Stodolka *et al*. 2017]. However, we have found a complete lack of studies devoted to the analysis of the tension of muscles in different karate stances. The possible reason for this is difficulties in measuring of muscles tension during stance performance. The proposed solution could be the measurement of the electrical activity of muscles as the indirect indicator of the level of their contractile activity [Weiss *et al*. 2016]. Based on this approach, we performed a study that revealed the basic patterns of the internal model of activation of skeletal muscles of the lower extremities of karate athletes during the performance of several basic stances.

The aim of the study was to assess the activity of some muscles of karate athletes during the performance of the basic stances of Kyokushinkai karate. The task was to investigate the amplitude and frequency characteristics of the surface electromyogram of the muscles of the lower extremities during the performance of the Fudo dachi and Kokutsu dachi stances, which are the basic elements for a number of techniques (strokes, blocks, etc.)

Methods

This study involved 16 male *Kyokushinkai karate* athletes of high sports qualification (1 dan), aged 18-25, with training experience in karate for 12–17 years. The procedures were accorded to the ethical standards of the relevant national, institutional or other body responsible for human research and experimentation, and to the principles of the World Medical Association's Declaration of Helsinki. This study was approved by the Ethical Committee of Lviv State University of Physical Culture named after Ivan Boberskyj. The experiments were performed in the scientific laboratory of the Department of Anatomy and Physiology of Ivan Bobersky Lviv State University of Physical Culture.

Surface electromyogram (sEMG) was recorded by Neuro-MVP-Micro device (Neurosoft LLC, Russian Federation) according to standard requirements [Weiss *et al*. 2016]. During the sEMG recording the disposable argentum-chlorine electrodes were used, the recording electrode was placed on the skin of the subject over the localization of the motor point of the muscle [Nikolaev 2010]. The distance between the active and reference electrodes was 2 cm. The electrical activity of the following muscles of the lower extremities of the right and left sides of the body was recorded: *m. gluteus maximus, m. rectus femoris, m. biceps femoris, m. semitendinosus, m. gasterocnemius (caput lateralis), m. tibialis anterior.*

The analysis of sEMG record was performed by the "Neuro-MVP.NETω" software (version 3.01.29.0). The average amplitude (μV), the average frequency (Hz) of sEMG has been determined [Weiss *et al*. 2016]. The MVC-normalization (based on electrical activity

recording during maximum voluntary contraction prior to the test) of sEMG was used. The amplitude and frequency characteristics of sEMG, obtained during MVC, were taken as 100%. Further, sEMG parameters were determined during the performance of the Fudo dachi and Kokutsu dachi (right leg in the front) stances. The values of amplitude and frequency of sEMG, recorded during the stances performance, were described as a percentage of those obtained under maximum voluntary contraction.

Standard statistical methods were used to calculate the means and standard deviations. A paired t-test or, when appropriate, a paired Wilcoxon test, was used to detect the presence of systematic difference, based on the Shapiro–Wilk criterion of data distribution. All values are given as arithmetic mean ± SEM (standard error of the mean). Statistical significance was set at $p = 0.05$ level for all analyses. Statistical analysis was carried out using MS Excel 2010 and OriginPro 9.1.

Results

Analysis of the electrical activity of the muscles of the lower extremities of karate athletes during the Fudo dachi performance revealed that the average amplitude and average frequency of sEMG are low. Both values do not exceed 38% of the maximum level (Fig. 1).

The lowest level of electrical activity was found for the *m. gluteus maximus* (about 8% of the maximum), while the highest levels of electrical activity were observed in the case of two leg muscles – *m. gastrocnemius (caput lateralis)* and *m. tibialis anterior*. The average amplitude of the sEMG of *m. gasterocnemius (caput lateralis)* reached 37-38% of the maximum, and the average frequency – 28-29%. The mean sEMG amplitude of the anterior leg muscles was slightly lower (24-26%), although their mean sEMG frequency was quite significant (29-35%).

The maintenance of an upright posture of the body causes a sufficiently high level of the electrical activity of the knee extensors, in particular *m. rectus femoris* (average sEMG amplitude – 19%). However, the activity of the knee flexors was also significant and for the *m. biceps femoris* was almost the same (21–23%) as in the case of *m. rectus femoris*. There is a tendency to a higher level of electrical activity, and probably tension, of *m. biceps femoris* compared to *m. semitendinosus*. We found no significant difference ($p > 0.05$) in the mean amplitude and frequency of sEMG of the similar muscles of the right and left parts of the body of athletes. The greatest differences are observed in the case of the muscles of the posterior thigh, but they do not reach significant values (P = 0.15¬-0.39).

The Kokutsu dachi stance was characterized by a high level of the electrical activity of some muscle groups and the presence of significant right-left asymmetry of sEMG values (Fig. 2). The highest average sEMG amplitude was found for the right *m. gasterocnemius (caput lateralis)* (58% of maximum) and left *m. tibialis anterior* (46% of the maximum). The average sEMG frequency of these muscles also reached significant values – 71% and 62% of the maximum value, respectively.

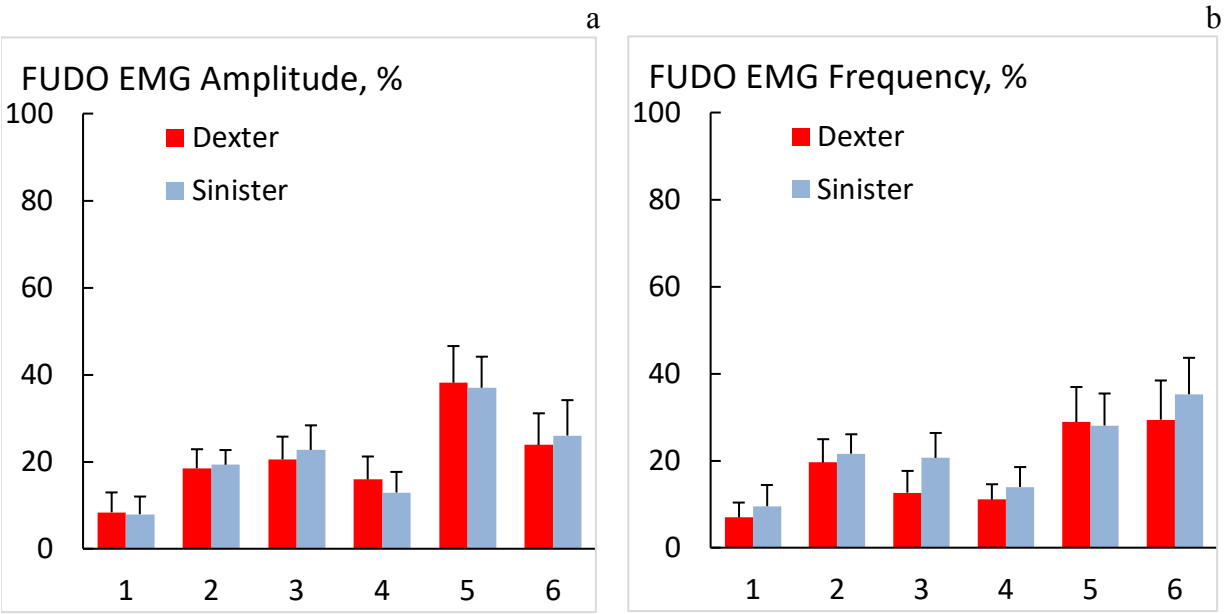

Fig. 1. The average amplitude (a) and average frequency (b) of the sEMG of the muscles of karate athletes during the performance of the Fudo dachi stance. The sEMG values are given as a percentage of the maximum level for the following muscles: 1 – *m. gluteus maximus*; 2 – *m. rectus femoris*; 3 – *m. biceps femoris*; 4 – *m. semitendinosus*; 5 – *m. gasterocnemius (caput lateralis)*; 6 – *m. tibialis anterior.*

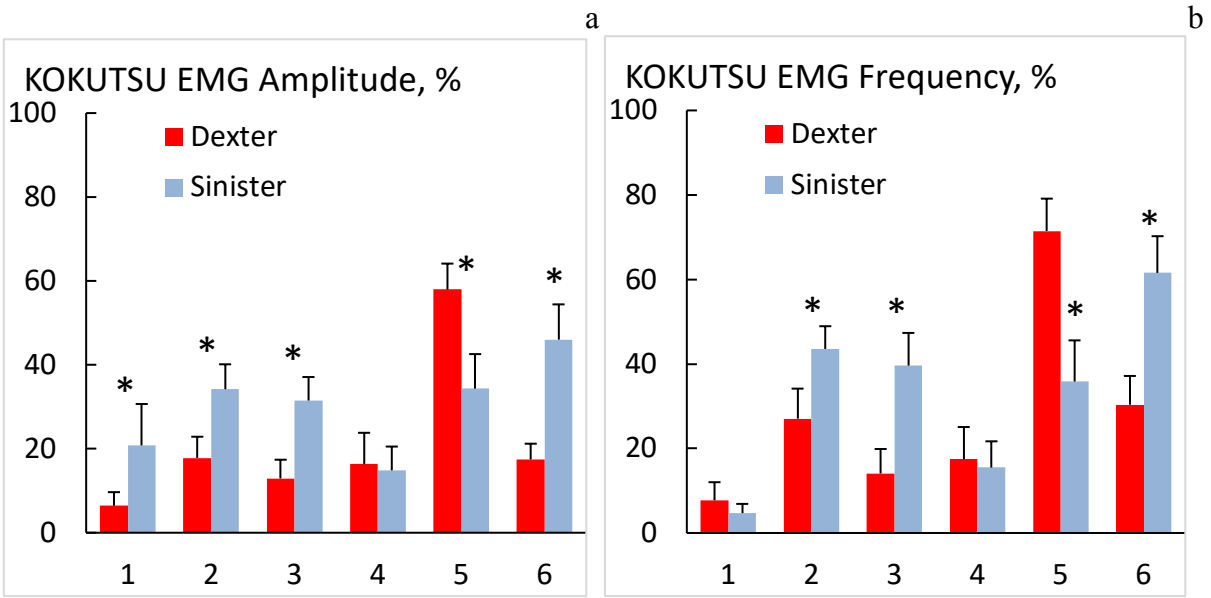

Fig. 2. Mean amplitude (a) and mean frequency (b) of the sEMG of the karate muscles during the performance of the Kokutsu dachi stance. The sEMG values are given as a percentage of the maximum level for the following muscles: 1 – *m. gluteus maximus*; 2 – *m. rectus femoris*; 3 – *m. biceps femoris*; 4 – *m. semitendinosus*; 5 – *m. gasterocnemius (caput lateralis)*; 6 – *m. tibialis anterior*. Asterisks (*) indicate a significant ($p < 0.05$) difference between the same muscles of the right and left extremities of the athlete

When comparing the sEMG values in similar muscles of the athlete's right lower extremity, registered in the Fudo dachi and Kokutsu dachi stances, a significant difference was found only for the *m. gasterocnemius (caput lateralis)*, whose activity was significantly higher in the Kokutsu dachi stance ($p < 0.05$). Among the muscles of the left lower extremity, the electrical activity of *m. rectus femoris* and *m. tibialis anterior* was larger in the Kokutsu dachi ($p < 0.05$). The average amplitude of their sEMG was 80% and the frequency was 80–100% higher ($p < 0.05$) than in Fudo dachi. It should be noted that for the Kokutsu dachi stance, the higher ($p < 0.05$) average sEMG frequency was also detected for the left *m. biceps femoris*, as compared to the Fudo dachi one.

Concerning the right-left asymmetry of sEMG values, we have found that in the Kokutsu dachi stance the average amplitude and frequency of sEMG of right *m. gasterocnemius (caput lateralis)* significantly (70% and 97%, respectively) exceed the activity of symmetrical muscle of the left leg ($p < 0.05$). At the same time, for many muscles of the left extremity (*m. gluteus maximus, m. rectus femoris, m. biceps femoris, m. tibialis anterior*) the higher values of average amplitude (1.9–3.2 times) or frequency 1.6–2.8 times) of sEMG were detected ($p < 0.05$).

Discussion

Our data allow us to analyze the compliance of the level of the electrical activity of the muscles of karate athletes, which reflects the strength of their contraction (tension), to the requirements for the performance of the stances. In particular, the low level of the electrical activity of the muscles in Fudo dachi stance is due to the fact that this stance is mainly used for rest between exercises or in anticipation of instructions [Oyama 2004; Cook 1985]. The lack of differences between sEMG values in similar muscles of the right and left parts of the body of athletes, which we found during Fudo dachi performance, fully correspond to the symmetrical nature of the stance. It also can be assumed that the percentage of active motor units in the muscles of the posterior surface of the lower leg was higher than that of the anterior one, which is due to the need to maintain an upright position of the body. The sufficient level of muscle tension of the anterior group of the lower leg was achieved to a greater extent by increasing the firing rate of motoneurons.

At the same time, the relatively high activity of knee flexors (21–23% of the maximum) and the foot dorsiflexors (24–26%) in Fudo dachi stance is found to be somewhat unexpected. A plausible explanation is the athletes' attempt to fix the position of the knee and ankle joint by tensing the antagonist muscles. This technique may require some correction to slow down the development of muscle fatigue with prolonged stance performance.

The Kokutsu dachi allows quick motions with short movements, and is mainly used as a defense stance, but also allows the effective counterattack performance. During this stance performance, 70% of body weight should be transferred to the back leg. The front leg must be slightly bent at the knee, the back must be straight, the toe of the front foot should be directed forward

[Oyama 2004; Cook 1985]. That is why, in the case of correct performance we might expect the large bilateral asymmetry in the strength of muscles contraction (tension) of lower extremities of karatekas during the Kokutsu dachi performance.

Our results were generally found to be in good agreement with the description of the correct Kokutsu dachi performance. We found a significant difference ($p < 0.05$) in the electrical activity of most symmetrical muscles of the left and right legs of the athlete, except the *m. semitendinosus*, in the Kokutsu dachi stance. The asymmetrically high levels of the electrical activity of the muscles of the back-positioned lower extremity (the left one) are consistent with the need to maintain a significant percentage of body weight. Thus, during the performance of the Kokutsu dachi stance, there is a higher level of tension on the left ankle dorsiflexors and both the knee flexors and extensors (apparently to fix the position of the knee joint), as well as the right ankle plantar flexors compared to those in the Fudo dachi stance. Therefore, it can be assumed that the performance of the Kokutsu dachi stance occurs under the condition of the predominance of the tension of the plantar flexors of the right ankle and the extensors of the hip, knee, and ankle dorsiflexors of the left lower extremity (back-positioned) of the athlete. Higher values of the sEMG frequency compared to the amplitude confirm the previously found predominance of the mechanism of increasing the firing rate of motoneurons over the mechanism of recruitment of additional motor units while providing the necessary force of static contraction of the athlete's skeletal muscles in the stance.

However, we have found a high level of activity of the ankle plantarflexor of the front leg of the athletes in Kokutsu dachi stance. Although this is generally consistent with the need to keep the ankle joint in an unbent position (the heel is detached from the ground), it may indicate increased muscle tension as a result of subconscious readiness to perform rapid kicks or movements.

Conclusions

1. A low level of average amplitude and frequency of sEMG in the athlete's muscles during the performance of the Fudo dachi stance (not more than 38% of the maximum level) was revealed. Maintaining a vertical posture of the body causes a high level of electrical activity of the knee extensors and the stabilization of the knee joint – increased activity of the knee flexors. No significant right-left asymmetry of sEMG values was detected.
2. The electrical activity of the muscles in the athlete's lower extremities reach high values during the performance of the Kokutsu dachi stance – the average amplitude of the sEMG of the right m. gasterocnemius reached 58%, and the left m. tibialis anterior – 46% of the maximum. During maintenance of the Kokutsu dachi stance, a high level of tension in the plantarflexors of the right ankle and the extensors of the hip, knee, and ankle dorsiflexors of the left lower extremity was determined. We found a high level of right-left asymmetry for sEMG values in the leg muscles.
3. Comparison of the sEMG values in the karate athletes' lower extremities muscles with descriptions of the proper technique for the performance of the stances allowed the internal models of muscle activity management to be analysed and revealed some features of the performance of the exercise An improvement in stance performance may be suggested on the basis of a conscious decrease in some muscles tension.

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Perspektywy poprawy postawy w karate na podstawie analizy elektromiogramu

Słowa kluczowe: karate kyokushinkai, fudo, dachi, kokutsu, dachi

Streszczenie

Tło. Wykonanie ćwiczeń można znacznie poprawić na podstawie szczegółowej analizy aktywności mięśni, którą można badać rejestrując ich aktywność elektryczną. Celem autorów było zbadanie aktywności niektórych mięśni karateków podczas wykonywania pozycji sportowych *karate kyokushinkai*.
Metody. Uczestnikami badania było 16 wysoko wykwalifikowanych (1 dan, 12-17 lat doświadczenia) mężczyzn w wieku 18-25 lat, praktykujacych *karate kyokushinkai*. Elektromiogram powierzchniowy (sEMG) został zarejestrowany podczas wykonywania podstawowych pozycji sportowych *Fudo dachi* i *Kokutsu dachi*. Zarejestrowano aktywność elektryczną mięśni m.in. *m. gluteus maximus, m. rectus femoris, m. biceps femoris, m. semitendinosus, m. gasterocnemius (caput lateralis), m. tibialis anterior*
Wyniki. Stwierdzono niskie (do 38% maksimum) poziomy i symetrię prawo-lewo średniej amplitudy i częstotliwości sEMG w przypadku *Fudo dachi*. Jest to zgodne z właściwą techniką wykonania pozycji. Jednak aktywność elektryczna niektórych zginaczy nóg (do 23%) i stóp (do 26%) była nieoczekiwanie wysoka, co może przyspieszyć rozwój zmęczenia. Stwierdzono wyższe poziomy wskaźników sEMG zginaczy grzbietowych lewej kostki, zginaczy i prostowników lewego kolana, a także zginaczy podeszwowych prawej kostki w *Kokutsu dachi* w porównaniu z pozycją w *Fudo dachi*. Najwyższy poziom amplitudy sEMG zarejestrowano dla *m. gasterocnemius d.* (do 58%) oraz *m. tibialis anterior s.* (do 46%). Dwustronną asymetrię w indeksach sEMG stwierdzono dla większości mięśni nóg, z wyjątkiem m. półścięgna |(*m. semitendinosus)*. Stwierdzono nieoczekiwanie wysoki poziom aktywności zginacza podeszwowego kostki przedniej nogi.
Wnioski. Porównanie danych sEMG z opisami wykonywania pozycji sportowych pozwoliło na opracowanie modeli aktywności mięśni podczas ćwiczeń oraz założenie pewnych szczególnych cech w technice wykonywania postaw.