Molecular & Cellular Biomechanics
DOI:10.32604/mcb.2020.011236
Article

The Kinematics and Surface Electromyography Characteristics of Round Kick of Martial Arts Athletes

Xin Wang*

Department of Command and Tactics, Henan Police College, Zhengzhou, 450046, China
*Corresponding Author: Xin Wang. Email: wxinxw@yeah.net
Received: 28 April 2020; Accepted: 11 August 2020

Abstract: In order to improve the level of athletes, modern scientific and technological means can be used to understand the characteristics and rules of movement. This study mainly analyzed the whip leg technique of Sanda athletes. Taking ten athletes as an example, the kinematics and surface electromyography (sEMG) data of them were measured, calculated and sorted out when they were doing the action of round kick. The results showed that the movement completion time of the first-level athletes was shorter, 0.34 ± 0.33 s. In the stage of turning hip and hitting, the angle of hip joint increased significantly. In the stage of turning hip, there was a significant difference in the angle of hip joint between different levels of athletes ($p < 0.05$), and there was no significant difference in other kinematics characteristics. In the aspect of sEMG, the duration of muscle discharge of the first-level athletes was shorter, but there was no significant difference in integrated electromyogram (IEMG) and root mean square (RMS). The experimental results reveal the importance of hip joint in the course of round kick and provide some theoretical bases for improving the level of athletes and carrying out targeted training.

Keywords: Kinematics; martial arts; round kick; surface electromyography; Sanda

1 Introduction

Chinese Wushu has a long history. It originated in the Shang and Zhou Dynasties and reached its peak in the Song and Ming Dynasties. Sanda is one of the competition forms of Wushu and is also known as Sanda. It is a kind of attack and defense technology which combines kicking, hitting and throwing, which has been widely concerned in the world. Its competition is increasingly fierce. In order to make Sanda players maintain a high level of competition, the kinematics of technical movement and surface electromyography (sENG) can be analyzed to understand the characteristics and laws of the movement [1]. The effect of kinematics and sEMG has obtained good results in motion research of many fields [2,3]. Slater et al. [4] analyzed the joint angle and other indexes of 21 elite female rhythmic gymnasts when they landed, found that the vertical ground reaction force (vGRF) of the athletes with larger hip joint bending angle was smaller, and pointed out that the range of lower limb bending should be increased to reduce the impact force when landing. Nedergaard et al. [5] studied the air bubble technique of seven ski cross athletes and found that the peak vertical force of the athletes was small and the range of knee joint movement was large in the launching stage and that the hip joint extension was obvious in the tension stage. Preuschl et al. [6] studied the kinematic characteristics of the jumping front-leg axe-kick of 22 male taekwondo athletes, found that there were significant differences in pelvic tilt angle displacement and hip extension angular speed between the athletes, and pointed out that the athletes could lift the legs early, extend the hip, and keep upright to obtain a large impact speed. Róisín et al. [7] studied 15 shot putters, compared the activities of bilateral rectus femoris, biceps femoris and medial and lateral gastrocnemius muscles, and found that the former two played an important role in sports. Ermolao et al. [8] studied the sports injury of a 29 year old professional volleyball player and found through EMG examination that the upper, middle and lower parts of the right trapezius muscle were innervated due to the axon cutting of the spinal accessory nerve (SAN), which may be caused by improper use of weight-lifting machine. Samaan et al. [9] analyzed the biomechanics of the lower limbs of a university athlete before and after ACL reconstruction, compared the kinematics and torque of the lower limb joints, and found through star exception balance test (SEBT) and single leg hop (SLH) that the athletes showed similar jumping distance before and after Anterior Cruciate Ligament reconstruction. Round kick is one of the skills of Sanda athletes, which has powerful killing power and is one of the most frequently used and most effective technical actions in the competition. However, there are few studies concerning round kick, and the study is not comprehensive. In this study, the action of round kick of the first-level and second-level athletes was comprehensively compared in aspects of kinematics and sEMG, which provides relative comprehensive data for the study of round kick technique, some theoretical bases for the improvement of round kick level and the formulation of reasonable training plan, and some theoretical references for the study on other actions of martial arts athletes.

2 Research Subjects and Methods

2.1 Research Subjects

Ten members of the martial arts Sanda team of Henan Police College, including five first-level and five second-level athletes, who had no physical injury and were in good physical condition, were selected. They all took the right hand and right leg as the dominant hand and leg, understood the basic content of the experiment, and signed the informed consent. The general information of the research subjects is shown in Tab. 1.

Table 1: General information of athletes

Level	Number	Age/year	Height/cm	Weight/kg	Training years/year
The first level	5	21.36 ± 1.89	170.31 ± 5.46	67.18 ± 10.23	7.46 ± 3.89
The second level	5	19.78 ± 2.13	171.46 ± 5.27	68.64 ± 10.46	5.89 ± 4.07

2.2 Research Methods

2.2.1 Experimental Equipment

VICON System 3D infrared high-speed motion capture system (Shanghai Xingzhou Digital Technology Co. Ltd., China) (Fig. 1) [10] with T40s camera, 4 million pixels and sampling frequency of 300 Hz was used. Kinematic data were collected and processed through VICON Nexus 1.85.

NORAXON-DTS EMG test system (Shanghai Xingzhou Digital Technology Co., Ltd., China) (Fig. 2) [11] with 300 Hz sampling frequency was used, and the EMG data was collected and processed through the supporting software MyoResearch XP Master Edition 1.08.16.

LT-8 physical therapy paste electrode (Shanghai Litu Medical Appliances Co., Ltd., China) (Fig. 3) whose diameter of adhesion area was 30 mm and diameter of conduction area was 10 mm was used.

Figure 1: Motion capture system

Figure 2: EMG test system

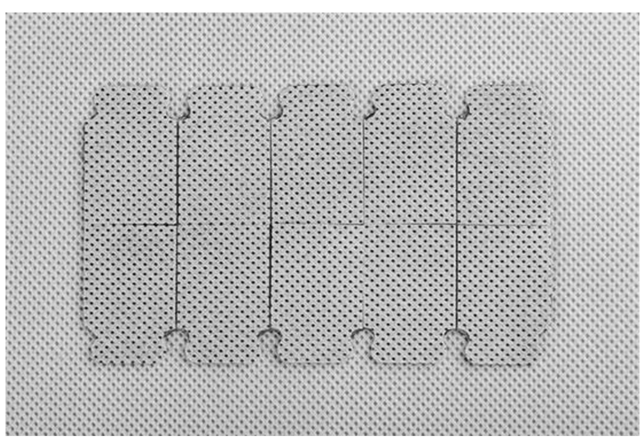

Figure 3: Experimental EMG pieces

2.2.2 Test Steps

1. The experimental instrument were preheated and calibrated. The research subjects were numbered. They were asked to warm up fully.
2. The pasting point of the electrode was determined: since all the subjects took the right leg as the dominant leg, the pasting position of the electrode was the right lateral obliquus externus

abdominis muscle, rectus femoris, biceps femoris, and lateral head of gastrocnemius muscle, as shown in Fig. 4.

3. The surface of the pasting point was cleaned with 75% medical alcohol, and the hair was shaved. Then the electrode was pasted by professional personnel.
4. The motion capture system and EMG test system worked at the same time. After the researchers gave the start signal, the subjects immediately made the action of round kick. After an interval of one minute, they performed the action again, three times in total.

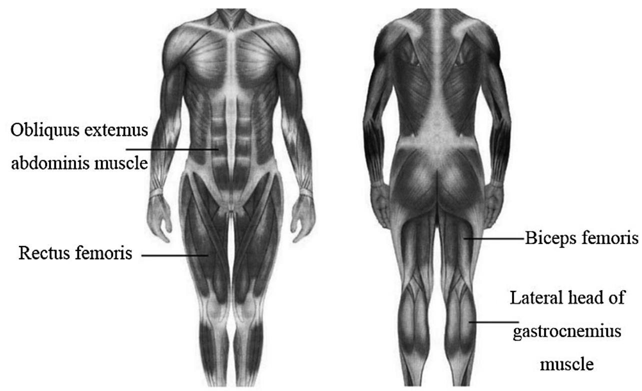

Figure 4: The pasting position of electrode

2.2.3 Analysis of Round Kick Movement

Process of round kick: the upper body was turned slightly to the left, the center of gravity of the body was moved to the left leg. The right leg slightly bended, with the knee lifted. The hip thrust out, and the knee was fastened. The instep was stretched. The knee joint was opened forward to make the shank flick from the outside, and then the shank fell back to the basic position. In the process of action, the strength was strengthened by twisting the waist. After hitting the target, the instep was tightened to protect the ankle joint. In order to facilitate the research, the round kick was divided into three steps: (1) knee lifting (Fig. 5a): from the transfer of center of gravity to the right leg knee lifting; (2) hip rotation (Fig. 5b): twisting the hip joint to generate force; (3) hitting (Fig. 5c): the knee of the right leg extends to generate force and falls back after hitting the target.

(a) (b) (c)

Figure 5: The action of round kick

2.2.4 Statistical Analysis

The data were calculated and sorted by EXCEL 2007 and expressed by X ± SD. The statistical analysis was performed by SPSS 17.0 software. If $p < 0.05$, the difference was statistically significant.

3 Research Results

3.1 Kinematic Analysis

3.1.1 Action Time

Action time refers to the total time for athletes to complete the action of round kick, and the time spent by every athlete is shown in Tab. 2.

It was seen from Tab. 2 that the action time of the athletes was very short; the average action time of the first level athletes was 0.34 ± 0.03 s, and the average action time of the second level athletes was 0.39 ± 0.03 s ($p < 0.05$), which showed that there were obvious differences in the action time of the athletes at different levels and the higher level athletes had shorter time to complete the action.

Table 2: Comparison of action time

Level	Number	Action time/s
First level	1	0.34 ± 0.03
	2	0.36 ± 0.02
	3	0.33 ± 0.03
	4	0.35 ± 0.03
	5	0.33 ± 0.02
Second level	6	0.39 ± 0.02
	7	0.38 ± 0.03
	8	0.40 ± 0.03
	9	0.39 ± 0.03
	10	0.41 ± 0.02

3.1.2 Analysis of Knee Lifting Stage (Stage 1)

It was seen from Tab. 3 that the angles and velocities of joints were small in Stage 1; the angles of the hip, knee and ankle of the first level athletes were 120.67 ± 5.49°, 85.36 ± 3.67° and 121.52 ± 4.85° respectively, and the velocities were 2.58 ± 0.32 m/s, 4.36 ± 0.29 m/s and 2.33 ± 0.53 m/s respectively; the angles of the hip, knee and ankle of the second level athletes were 119.77 ± 4.39°, 87.64 ± 3.48° and 120.36 ± 5.02° respectively, and the velocities were 2.69 ± 0.41 m/s, 4.38 ± 0.27 m/s and 2.34 ± 0.49 m/s respectively; the angle of the knee joint was the smallest, and there was no significant difference between the first level and the second level athletes.

Table 3: Comparison of the joint angle and velocity in Stage 1

		First level	Second level
Hip joint	Angle (°)	120.67 ± 5.49	119.77 ± 4.39
	Velocity (m/s)	2.58 ± 0.32	2.69 ± 0.41
Knee joint	Angle (°)	85.36 ± 3.67	87.64 ± 3.48
	Velocity (m/s)	4.36 ± 0.29	4.38 ± 0.27
Ankle joint	Angle (°)	121.52 ± 4.85	120.36 ± 5.02
	Velocity (m/s)	2.33 ± 0.53	2.34 ± 0.49

3.1.3 Analysis of Hip Rotation Stage (Stage 2)

Tab. 4 shows angles and velocities of the joints in Stage 2. It was seen from Tab. 4 that the angles of joints had obvious changes in Stage 2, which were significantly larger than those in Stage 1; the variation amplitude of the ankle joint was relatively small, and the variation amplitudes of hip and knee joints was relatively large; velocities of knee and ankle joints in Stage 2 were also larger than those in Stage 1. The comparison between the first level and second level athletes showed that the hip joint angle of the first level athletes was 147.23 ± 4.36°, while that of the second level athletes was 127.45 ± 5.64° ($p < 0.05$); the hip joint velocity of the second level athletes was larger, but the difference was not significant.

Table 4: Comparison of joint angle and velocity in Stage 2

		First level	Second level
Hip joint	Angle (°)	147.23 ± 4.36	127.45 ± 5.64*
	Velocity (m/s)	1.97 ± 0.21	2.33 ± 0.36
Knee joint	Angle (°)	134.28 ± 4.32	133.64 ± 3.69
	Velocity (m/s)	6.46 ± 1.27	6.55 ± 1.08
Ankle joint	Angle (°)	141.46 ± 7.68	139.45 ± 8.12
	Velocity (m/s)	9.48 ± 2.16	9.54 ± 2.31

* Compared with the first level athletes, $p < 0.05$.

3.1.4 Analysis of Hitting Stage (Stage 3)

Tab. 5 is the comparison of joint angle and velocity in Stage 3. It was found that angles of different joints still maintained large values. In terms of velocity, the hip and knee joints were small, and the velocity of the ankle joint was large, which was because that the ankle joint needed to be kicked out quickly to hit the target directly in the hitting stage; there was no significant difference between the first level and second level athletes.

Table 5: Comparison of joint angle and velocity in Stage 3

		First level	Second level
Hip joint	Angle (°)	146.48 ± 5.64	142.21 ± 7.88
	Velocity (m/s)	1.15 ± 0.11	1.17 ± 0.12
Knee joint	Angle (°)	147.56 ± 2.18	147.66 ± 2.67
	Velocity (m/s)	2.16 ± 0.33	2.27 ± 0.29
Ankle joint	Angle (°)	135.69 ± 8.64	136.78 ± 7.86
	Velocity (m/s)	13.46 ± 2.36	13.33 ± 2.48

3.2 Analysis of sEMG Characteristics

It was seen from Fig. 6 that the discharge duration of the lateral head of gastrocnemius muscle was the longest, 1.03 ± 0.26 s and 1.27 ± 0.33 s, respectively, and that of biceps femoris muscle was the shortest, 0.65 ± 0.55 s and 0.97 ± 0.61 s, respectively; the discharge duration of the second level athletes was longer, but there was no significant difference between the first level and second level athletes.

The integrated electromyogram (IEMG) of muscles is shown in Fig. 7.

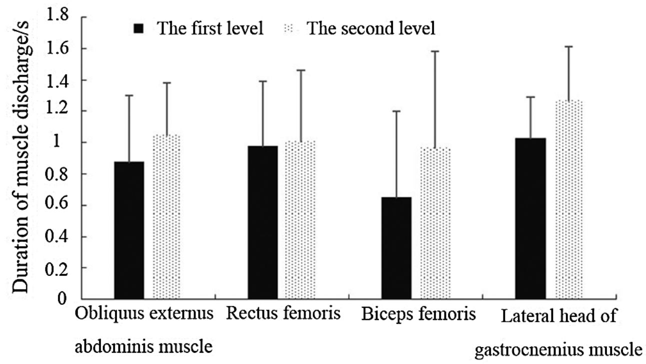

Figure 6: Duration of muscle discharge

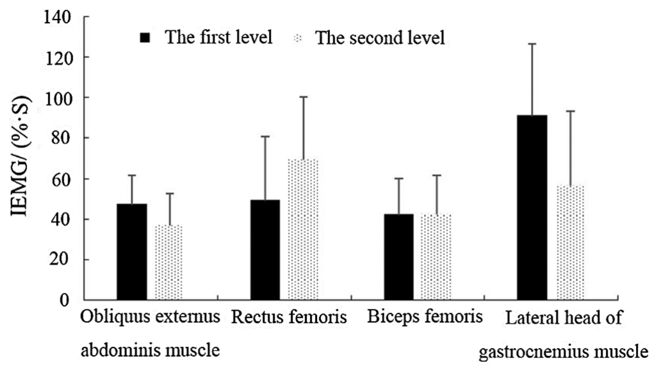

Figure 7: Comparison between IEMG values

It was seen from Fig. 7 that the IEMG value of the lateral head of gastrocnemius muscle of the first level athletes was the largest, and that of the biceps femoris muscle was the smallest; the IEMG value of the rectus femoris muscle of the second level athletes was the largest, and that of the external oblique abdominal muscle was the smallest. Except for the rectus femoris muscle, the IEMG of the second level athletes was smaller than that of the first level athletes, but $p < 0.05$, i.e., there was no significant difference.

A comparison of the root mean square (RMS) values of muscles is shown in Fig. 8.

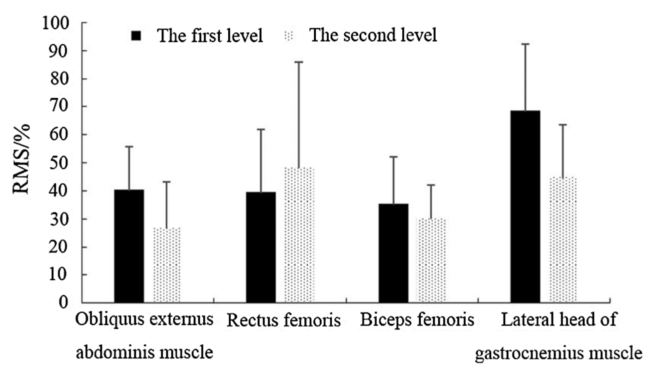

Figure 8: Comparison of RMS value

It was seen from Fig. 8 that the RMS of the lateral head of gastrocnemius of the first level athletes was the largest, that of the biceps femoris was the smallest; the RMS of the rectus femoris of the second level athletes was the largest, and that of the external oblique abdominal muscle was the smallest. RMS can reflect the time of muscle activity. The muscles with long activity time of the first level and the second level athletes were respectively the lateral head of gastrocnemius and rectus femoris. The comparison showed that the RMS of the external oblique abdominal muscle, biceps femoris and lateral head of gastrocnemius of the second level athletes were smaller, and that of rectus femoris was large, but there was no significant difference between the first level and second level athletes ($p < 0.05$).

4 Discussion

In the field of sports, the methods of kinematics and sEMG are applied. In terms of kinematics, the motion capture system can provide accurate data of human motion [12] and analyze and evaluate motions. sEMG has been applied in fields such as clinical medicine [13,14], rehabilitation medicine [15,16] and physical education [17,18]. It can determine the main driving muscles and understand the coordination of muscle activity [19]. This paper mainly studies from these two aspects.

The experimental results demonstrated that angles of hip and knee joints of athletes increased from small to large in the process of round kick; angles of hip and knee joints in Stages 2 and 3 were significantly larger compared with those in Stage 1. In addition, in Stages 2 and 3, the velocity of the hip joint was the smallest, followed by the knee joint and ankle joint, showing the characteristic that large joint driving small joint. Transferring momentum to the ankle joint is more conducive to the kick of the lower limb. The comparison between different levels of athletes demonstrated that there were some differences in the angle and the difference in velocity was small. In the hip rotation stage, the hip joint angle of the first level athletes was significantly larger ($p < 0.05$); from this point of view, the large hip joint angle provides great waist strength, so that the follow-up round kick achieved better results. In addition, in the whole process of round kick, the hip joint always maintains a small speed, and the speed change was very small, while the change of knee and ankle joints was obvious.

From the perspective of sEMG characteristics, this study mainly analyzed the muscle continuous discharge duration, IEMG and RMS. Firstly, the discharge duration of the lateral head of gastrocnemius muscle was long, and the continuous discharge duration of muscles of the second level athletes was longer than that of the first level athletes, which showed that their muscle contraction ability was slightly worse than that of the first level athletes. In order to improve the muscle performance, it is necessary to strengthen the strength and endurance training of muscles with long discharge duration. IEMG can reflect the main force generating muscles in the action process. The main force generating muscles of the first and second level athletes were the lateral head of gastrocnemius and rectus femoris. The size of RMS can reflect the time of muscle activity. It was seen from Fig. 7 that the RMS of rectus femoris and lateral head of gastrocnemius was large in the process of round kick and there was no significant difference between the athletes of different levels.

Based on the kinematics and sEMG characteristics of round kick, the main differences of athletes at different levels are as follows:

(1) the second level athletes took a little longer to complete the action;
(2) in the hip rotation stage, the range of hip rotation of the second level athletes was not enough and the angle of the hip joint was small;
(3) the duration of muscle continuous discharge of the second level athletes was long, and the strength of the lateral head of gastrocnemius muscle was not enough.

5 Conclusion

This study mainly studied the round kick technique of Wushu Sanda athletes, analyzed the characteristics of round kick from aspects of kinematics and sEMG, and compared the differences of different levels of athletes.

The experimental results suggested that the first level athletes had short action completion time, large hip joint angle, small joint velocity and short duration of muscle discharge. Therefore, in the training process, training of athletes needs to be strengthened based on those factors to improve the technical level of round kick.

Funding Statement: The author received no specific funding for this study.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References

1. Kwon, S., Pfister, R., Hager, R. L., Hunter, I., Seeley, M. (2017). Influence of tennis racquet kinematics on ball topspin angular velocity and accuracy during the forehand groundstroke. *Journal of Sports Science & Medicine, 16(4),* 505–513.
2. Leong, H. F., Lam, W. K., Ng, W. X., Kong, P. W. (2018). Center of pressure and perceived stability in basketball shoes with soft and hard midsoles. *Journal of Applied Biomechanics, 34(4),* 1–23. DOI 10.1123/jab.2017-0120.
3. Le Mansec, Y., Dorel, S., Hug, F., Jubeau, M. (2017). Lower limb muscle activity during table tennis strokes. *Sports Biomechanics, 17(4),* 1–11. DOI 10.1080/14763141.2017.1354064.
4. Slater, A., Campbell, A., Smith, A., Straker, L. (2015). Greater lower limb flexion in gymnastic landings is associated with reduced landing force: a repeated measures study. *Sports Biomechanics, 14(1),* 1–12. DOI 10.1080/14763141.2015.1029514.
5. Nedergaard, N. J., Heinen, F., Sloth, S., Holmberg, H. C., Kersting, U. G. (2015). Biomechanics of the ski cross start indoors on a customised training ramp and outdoors on snow. *Sports Biomechanics, 14(3),* 273–286. DOI 10.1080/14763141.2015.1052543.
6. Preuschl, E., Hassmann, M., Baca, A. (2016). A kinematic analysis of the jumping front-leg axe-kick in Taekwondo. *Journal of Sports Science & Medicine, 15(1),* 92–101.
7. Howard, R. M., Conway, R., Harrison, A. J. (2017). Muscle activation sequencing of leg muscles during linear glide shot putting. *Sports Biomechanics, 16(4),* 463–484. DOI 10.1080/14763141.2016.1246601.
8. Ermolao, A., Brogi, M., Baioccato, V., Rovai, S. (2019). Unsafe workout: a weak and painful shoulder in a professional volleyball player. *Case Reports, 12(5),* e228084.
9. Samaan, M. A., Ringleb, S. I., Bawab, S. Y., Greska, E. K., Weinhandl, J. T. (2018). Altered lower extremity joint mechanics occur during the star excursion balance test and single leg hop after ACL-reconstruction in a collegiate athlete. *Computer Methods in Biomechanics and Biomedical Engineering, 21(1–4),* 344–358. DOI 10.1080/10255842.2018.1452203.
10. Qian, J., Zhang, Y., Baker, J. S., Gu, Y. (2016). Effects of performance level on lower limb kinematics during table tennis forehand loop. *Acta Bioengineering & Biomechanics, 18(3),* 149.
11. Barfield, J., Newsome, L., Sallee, D., John, E. B., Malone, L. A. et al. (2015). EMG assessment of muscle fatigue in elite paralympic athletes. *Medicine & Science in Sports & Exercise, 47,* 419–420. DOI 10.1249/01.mss.0000477574.25228.c8.
12. Sá, F., Marques, A., Rocha, N. B. F., Trigueiro, M. J., Campos, C. et al. (2015). Kinematic parameters of throwing performance in patients with schizophrenia using a markerless motion capture system. *Somatosensory Research, 32(2),* 77–86. DOI 10.3109/08990220.2014.969838.
13. Berni, K. C. D. S., Dibai-Filho, A. V., Pires, P. F., Rodrigues-Bigaton, D. (2015). Accuracy of the surface electromyography RMS processing for the diagnosis of myogenous temporomandibular disorder. *Journal of Electromyography and Kinesiology, 25(4),* 596–602. DOI 10.1016/j.jelekin.2015.05.004.

14. Chada, A., Hoque, R. (2019). Images: periodic limb movements during sleep noted on ventral thigh surface electromyography in an above-the-knee amputated stump. *Journal of Clinical Sleep Medicine: JCSM: Official Publication of the American Academy of Sleep Medicine, 15(8),* 1183–1184.
15. Bar-On, L., Van Campenhout, A., Desloovere, K., Aertbeliën, E., Huenaerts, C. et al. (2014). Is an instrumented spasticity assessment an improvement over clinical spasticity scales in assessing and predicting the response to integrated botulinum toxin type A treatment in children with cerebral palsy? *Archives of Physical Medicine and Rehabilitation, 95(3),* 515–523. DOI 10.1016/j.apmr.2013.08.010.
16. Kim, S., Lee, D., Ko, J. Y., Park, Y., Yoon, Y. H. et al. (2019). The mechanism of hip dislocation related to the use of abduction bar and hip compression bandage in patients with spastic cerebral palsy. *American Journal of Physical Medicine & Rehabilitation, 98(12),* 1125–1132. DOI 10.1097/PHM.0000000000001261.
17. Al-Quraishi, M. S. S. (2017). Classification of ankle joint movements based on surface electromyography signals. *Medical & Biological Engineering & Computing, 55(5),* 747–758. DOI 10.1007/s11517-016-1551-4.
18. Hatamzadeh, M., Hassannejad, R., Sharifnezhad, A. (2020). A new method of diagnosing athlete's anterior cruciate ligament health status using surface electromyography and deep convolutional neural network. *Biocybernetics and Biomedical Engineering, 40(1),* 65–76. DOI 10.1016/j.bbe.2019.05.009.
19. Dong, Y., Wang, H., Zheng, Y. (2018). Analysis of surface electromyography of lumbo-abdominal muscles in patients with chronic low back pain under different vibration conditions. *Chinese Journal of Rehabilitation Medicine, 33(3),* 297–303.