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The electromyographic characteristics of the inner and outer forearm muscle groups in the basic movements of Tai Chi

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ABSTRACT

In order to solve the problem of fatigue of muscles such as the inner and outer forearms in current Tai Chi athletes who train under various loads for a long time, the author proposes a study on the electromyographic characteristics of muscles such as the inner and outer forearms in the basic movements of Tai Chi. The author first collected and recorded the electromyographic signals of the inner and outer forearm muscle groups of athletes, and transmitted the collected electromyographic signals to a computer using MegaWin software; Then, based on computer calculations and analysis, one-dimensional electromyographic time series signals are obtained. Based on this, the integrated electromyography, root mean square amplitude, and average power frequency and center frequency in the frequency domain are calculated in the time domain analysis; Finally, the calculation results will be used as the basis for analyzing the fatigue characteristics of muscle groups such as the inner and outer forearms of athletes. Statistical analysis methods will be used to obtain the relationship between parameters in the time domain and frequency domain, as well as the relationship between parameters and fatigue of muscle groups such as the inner and outer forearms of athletes. At the same time, SPSS software will be used to statistically analyze the differences between time domain parameters and frequency domain parameters to complete the analysis of upper limb muscle fatigue characteristics of athletes. The experimental results showed that the average consistency between the analysis results of the fatigue characteristics of the inner and outer forearm muscles of athletes based on surface electromyography and the actual situation was 98.3. When the analysis method of fatigue characteristics of the inner and outer forearm muscles of athletes based on surface electromyography took 0.6 hours, the energy consumption reached 83 nJ/bit. This method has high consistency between the analysis results and the actual situation, and low analysis energy consumption.

Keywords: Surface electromyography; Tai Chi athlete; Muscle groups on the inner and outer sides of the forearm; Fatigue characteristics; Time domain analysis; The relationship between parameters; Parameter difference

1.INTRODUCTION

Tai Chi is an outstanding representative of Chinese martial arts, and its influence in the world has far exceeded the individual significance of its martial arts. It has become a synonym for Chinese martial arts, and when it comes to Chinese martial arts internationally, Tai Chi is naturally mentioned [1]. Tai Chi not only improves the body's cardiovascular and immune functions, but also enhances the control of the nervous system and muscles. Tai Chi can improve balance and coordination skills and reduce the risk of falls in the elderly [2]. Tai Chi, as a traditional sport that can promote health and physical fitness, has been vigorously promoted [3]. In recent years, it has been confirmed by many studies that Tai Chi is beneficial for the treatment of lower limb osteoarthritis, improving the quality of life of the elderly, and prolonging their lifespan [4]. In the process of learning Tai Chi, it can be beneficial for Tai Chi Push Hands to master the movement characteristics of Tai Chi faster. Tai Chi is a technique that combines physical and practical skills. The Tai Chi frame is the body and the Tai Chi push hands are used. Tai Chi Pushing Hands, also known as Pushing Hands, Beating Hands, Rubbing Hands, and Uncovering Hands, are two person unarmed combat exercises in Tai Chi. The Tai Chi routines complement each other in the relationship between body and function, and play an important role in the teaching of Tai Chi [5]. At present, in the teaching and research of Tai Chi Push Hands, only the characteristics of its technical movements have been explored, and there have been few studies on the technical movements of Tai Chi Push Hands from the perspective of neuromuscular aspects [6]. Surface electromyography (sEMG) can provide non-invasive

evaluation of muscle function, and its application provides a scientific basis for exploring the exercise patterns of various sports and guiding exercise training [7].

With the promotion and development of Tai Chi culture, more and more fitness enthusiasts are using Tai Chi as a form of exercise, and research on Tai Chi exercise has become an inevitable trend [8]. Therefore, the author tested and analyzed the electromyographic characteristics during the basic movements of Tai Chi, focusing on muscle tension, muscle activation sequence, duration of work done by each group of muscles, and contribution rate of each group of muscles during the completion of the movements. This scientifically, comprehensively, objectively, and accurately analyzed the muscle exertion characteristics of Tai Chi basic movements, further deepening the understanding of the exertion characteristics of Tai Chi movements, and providing a scientific and effective theoretical basis for future training of Tai Chi movements [9].

2. LITERATURE REVIEW

Surface electromyography technology has been widely applied in various fields such as clinical science, sports medicine, and modern rehabilitation. In addition, it is also widely used in sports science research, such as sprint testing, tremor training testing, and instrument performance comparison. Research on electromyography can be traced back to the 17th century in foreign countries, while it started relatively late in China. The following is a summary of some researchers' research on surface electromyography in the field of sports science in recent years. There are many research results related to athlete fatigue injuries. Croom, A. M. and others introduced the initial Tai Chi program, including the goals, techniques, and combinations to be practiced throughout the entire 3-week program. This case study shows that a 3-week exercise plan based solely on Tai Chi can improve aerobic capacity, muscle mass, bone mass, basal metabolic rate, and daily calorie intake, and reduce resting heart rate, fat mass, body fat percentage, and visceral fat rating in previously sedentary individuals [10]. Croom, A. M. et al. presented the results of a preliminary empirical study on professional Muay Thai practitioners, which revealed how Tai Chi promotes their overall mental health by fostering positive emotions, engagement, relationships, meaning, and achievement [11]. The experimental results show that the method has good stability, but the energy consumption of the analysis method is relatively high. Yu ichi Noto et al. elucidated the characteristics of MU discharge frequency in ALS patients and its relationship with clinical factors through high-density surface electromyography (HDSEMG) and MU decomposition analysis.

Given the existing problems in the current analysis methods for the characteristics of athlete physical fatigue, the author proposes a method for analyzing the fatigue characteristics of muscle groups such as the inner and outer forearms of athletes based on surface electromyography.

3. METHOD

3.1 Collection and recording of electromyographic signals from the inner and outer forearm muscle groups of athletes

Regarding the collection of electromyographic signals: sEMG signals are recorded using the dual electrode guidance method. Among them, the electrodes will collect signals from various parts of the athlete's forearm muscles, including the inner and outer sides, based on the functions provided by Finland's MegaWin software. The electrode spacing is 3cm, and the reference electrode should be attached according to the requirements at this spacing. Use Mega's electromyography acquisition kit to collect sEMG signals, set the signal sampling frequency to 1000Hz, and after the signal acquisition is completed, transmit it to the computer through MegaWin software [12].

Tai Chi exercises are performed from the initial standing position (starting position) to the final return to standing position (closing position) (except for independent movements such as left and right foot kicks and left and right downward movements) while maintaining a certain height of the body's center of gravity, which is coordinated and coordinated with changes in the knee joint angles of the two lower limbs. The movement trajectory of each joint in Tai Chi exercise is not a straight line but a circular arc. Maintaining an upright posture during single leg support not only relies on the muscle strength of the lower limbs, but also on the coordination and cooperation of the upper and lower limbs in various parts of the body. The movement of the body center of gravity in Tai Chi is carried out after the end of the single foot support phase, that is, after the start of the two foot support phase. From the perspective of safety and stability, this is a reasonable movement characteristic. Tai Chi is a slow and graceful physical performance that requires each movement to have a style and shape that matches its name. Its movements are stable and safe. On the one hand, Tai Chi can be used as one of the better exercise methods for middle-aged and elderly people to maintain balance function or improve balance ability; On the other hand, it provides a certain objective basis for the relationship between Tai Chi practice and human balance ability [13-14].

3.2 Analysis of Fatigue Characteristics of Muscle Groups in the Forearm of Athletes under Surface Electromyography

According to computer analysis, the electromyographic signal is obtained as a one-dimensional time series signal. The characteristic of this electromyographic signal refers to the corresponding activity of surface electromyographic signals after muscle fatigue during exercise. This phenomenon is the result of muscle nerve control in athletes and is related to factors such as muscle movement patterns. The time domain can reflect the characteristics of the surface electromyographic signals of athletes' forearm muscles over time, including the integrated electromyographic level and average amplitude of the muscles [15]. Time domain analysis includes integrated electromyography (iEMG) and root mean square amplitude (RMS). IEMG refers to the area generated by electromyography in the electromyographic signals collected by electromyography instruments during muscle

movement, which can reflect the muscle condition in detail during a certain period of time.

The $X(t)$ one-dimensional electromyographic time series signal set $x_{(1)}\{x_1, x_2, x_3 \ldots x_t\}$ is obtained, and equation (1) is the expression for the integrated electromyographic iEMG:

$$\text{iEMG} = \int_{N_2}^{N_1} X(t) \quad (1)$$

In equation (1), N_1 represents the starting point of integration, and N_2 represents the endpoint of integration.

The root mean square amplitude represents the average value of electromyographic discharge during muscle movement. Research has shown that this phenomenon may be related to the amount of exercise and muscle fiber discharge [16]. Assuming only the root mean square value for a certain period of time, it may not fully express the detailed morphology and trend of the athlete's muscle integrated electromyography. In this case, the fatigue intensity value must be recalibrated. The expression for root mean square amplitude is shown in equation (2):

$$\text{RMS} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} \text{EMG}\ (X_i)^2} \quad (2)$$

In equation (2), N represents the number of sampled points, i represents the vibration coefficient, and X_i represents the electromyographic amplitude at each point after sampling. According to most research results, muscle RMS increases during fatigue.

Frequency domain analysis is the observation of the frequency characteristics of electromyographic signals generated by muscles during exercise, also known as spectral analysis. The spectral characteristics mainly include the average power frequency and center frequency. The formula for calculating the average power frequency MPF is shown in equation (3):

$$\text{MPF} = \frac{\int f S(f) \mathrm{d}f}{\int S(f) \mathrm{d}f} \quad (3)$$

In equation (3), f represents power, $\mathrm{d}f$ represents frequency resolution, and $S(f)$ represents power spectrum curve.

The center frequency F_c divides the power spectrum into two frequency domains with the same area, that is, the energy is divided into two frequency values. Related studies have shown that as athletes' exercise time increases, the center frequency value decreases. The expression for calculating the center frequency is:

$$F_c = \int_{F_S}^{F_e} S(f) \mathrm{d}f \quad (4)$$

In equation (4), F_S represents the starting frequency of the signal, and F_e represents the ending frequency of the signal.

By calculating in both time and frequency domains, the accuracy of analyzing fatigue characteristics of muscle groups such as the inner and outer forearms of athletes can be effectively improved [17].

Based on the above analysis and calculation, the observation indicators are set to compare the relationship between the athlete's upper limb muscle RMS、MPF、F_c, RMS、MPF、F_c at the beginning and end of the exercise, and the athlete's upper limb muscle fatigue.

Using statistical analysis methods to remove unnecessary movements during athletes' movements, in order to reduce energy consumption in analyzing upper limb muscle fatigue characteristics. At this stage, detecting differences in time-domain and frequency-domain values requires independent sample testing and statistical analysis. The above research data was statistically analyzed using SPSS software.

3.3 Experimental verification

In order to verify the overall performance of the surface electromyography based analysis method for fatigue characteristics of the inner and outer forearm muscles of athletes, the relationship between the average power frequency and center frequency of the surface electromyography signals of the wrist flexor and extensor muscles under different loads of maximum muscle strength in the inner and outer forearm muscles was compared, and different methods were used to compare the analysis results with the actual situation and energy consumption. In the experiment, 10 physically healthy athletes from the sports school were selected, including 5 male athletes and 5 female athletes [18]. The experimental subjects did not engage in intense activity for the two weeks prior to the experiment, and there were no muscle injuries in the inner or outer forearm muscle groups. After obtaining the consent of the experimental subjects, fatigue tests were conducted on the inner and outer muscles of the forearm. Table 1 shows the measurement indicators for athletes.

Table 1 Measurement indicators of experimental subjects

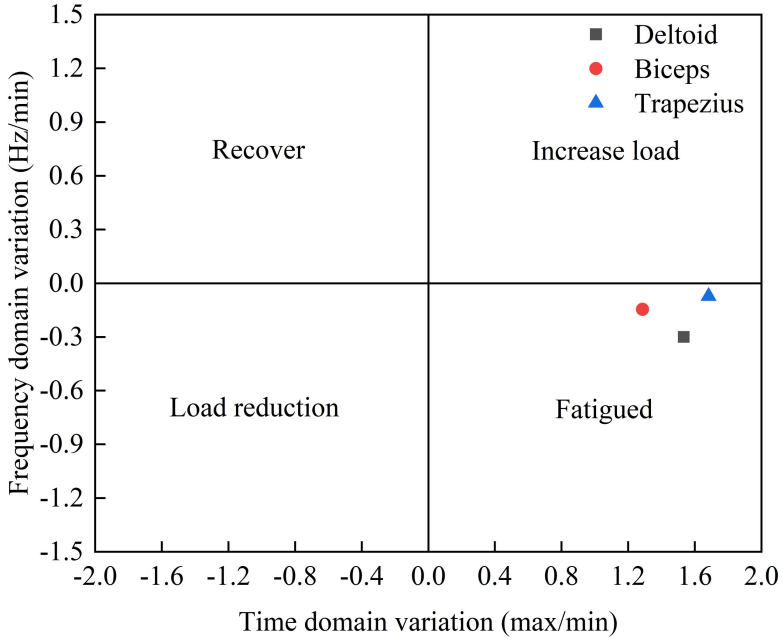
Measurement project	measurement result
Age/Year	16 ± 1
weight /kg	60 ± 0.4
height /cm	171 ± 5.1
Height /cm	134 ± 6.4
elbow height /cm	90 ± 10
Shoulder width /cm	67 ± 4

The experimental subjects remained upright and repeated muscle group movements on the inner and outer forearms for 2 minutes each time, for a total of 4 groups. Use an electromyography collection box to collect surface electromyography data of

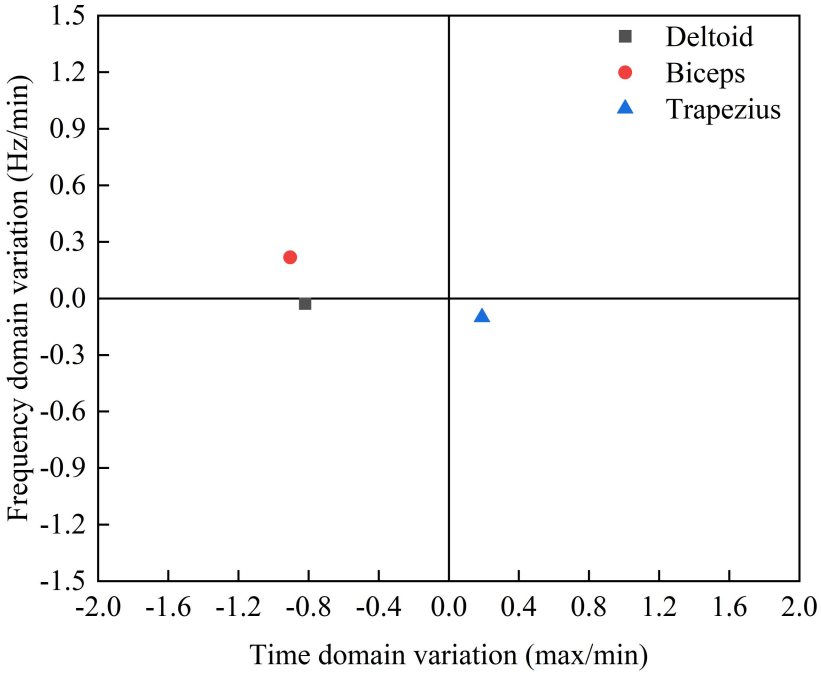
muscle groups such as the inner and outer forearms of athletes [19-20].

4. RESULTS AND DISCUSSION

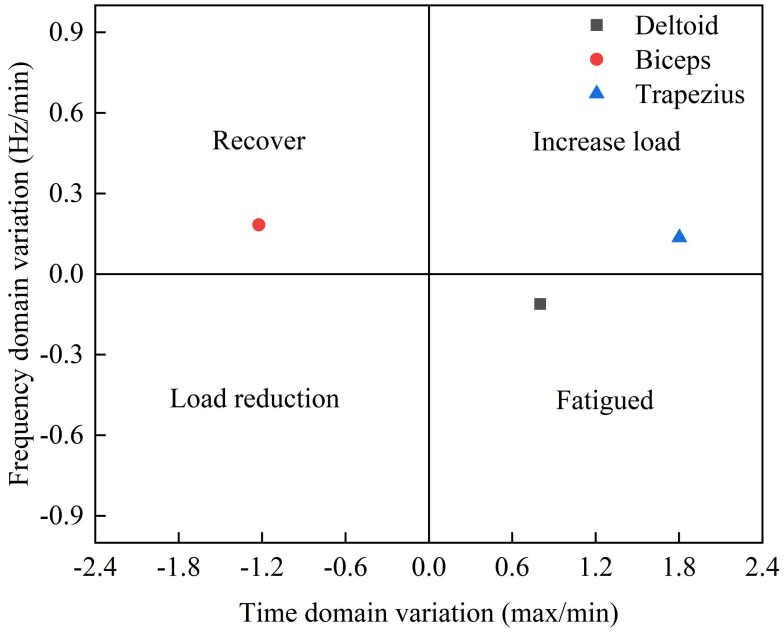
Figure 1 shows three groups, namely three stages of changes in the biceps, deltoid, and trapezius muscles. From Figure 1, it can be seen that the biceps brachii experienced one instance of fatigue, while the deltoid and trapezius muscles experienced two instances of fatigue. In the experiment, there was no decrease in load on all muscle groups such as the inner and outer forearms.



（a）



(b)



(c)

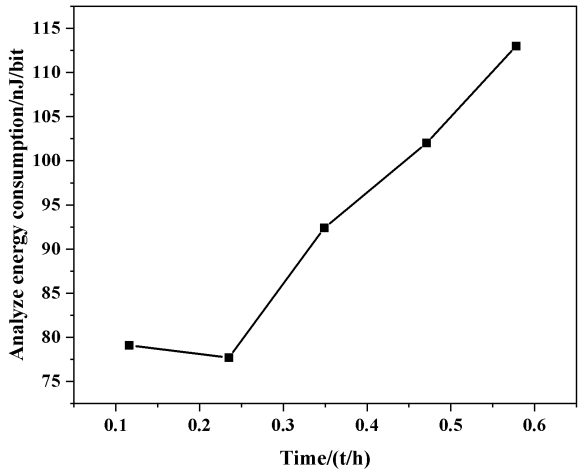
Figure 1 Changes in biceps, deltoid, and trapezius muscles in three stages

(a) The first stage involves changes in the biceps, deltoid, and trapezius muscles;

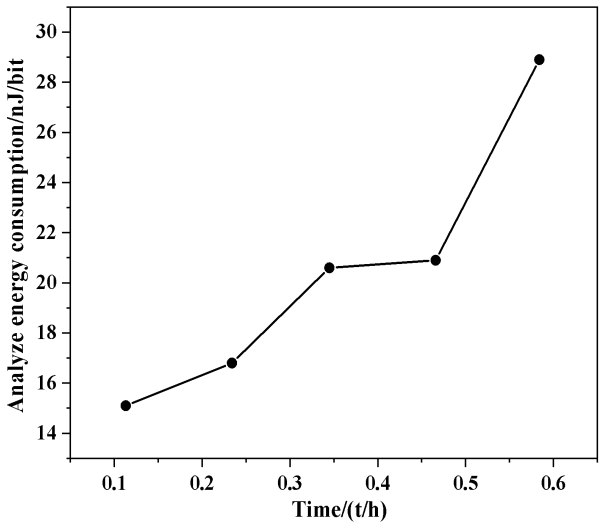
(b) The second stage involves changes in the biceps, deltoid, and trapezius muscles;

(c) The third stage involves changes in the biceps, deltoid, and trapezius muscles;

It can be clearly seen from Figure 2 (a) and (b) that the analysis method of fatigue characteristics of the inner and outer forearm muscles of athletes based on surface electromyography takes 0.6 hours and consumes 83 nJ/bit of energy. The method for analyzing common sports injuries in female judo athletes from a functional anatomy perspective takes 0.6 hours and consumes 115 nJ/bit of energy. From this, it can be seen that the analysis method of fatigue characteristics of upper limb muscles, such as the inner and outer forearms of athletes based on surface electromyography has lower energy consumption and stronger robustness compared to current methods.



(a)



(b)

Figure 2 Comparison of energy consumption analysis using different methods

The experimental platform is Matlab, and the experimental data is taken from the above research data. The experimental results are as follows: In Table 2, Q0 represents the number of test participants, Q1 represents the degree of agreement between the method analysis results and the actual situation in the screening of sports injury characteristics and risk factors for male college football players, Q2 represents the degree of agreement between the method analysis results and the actual situation in the impact of fatigue on the biomechanical characteristics of the lower limbs of badminton players' stepping movements, and Q3 represents the degree of agreement between the analysis results and the actual situation of the fatigue characteristics of the inner and outer forearm muscle groups of athletes based on surface electromyography.

Table 2 Comparison of the Consistency between the Analysis Results of Different Methods and the Actual Situation

Q0	Q1(%)	Q2(%)	Q3(%)
1	78.2	80.1	98.6
2	69.1	79.4	98.8
3	74.0	74.1	99.5
4	65.2	74.2	97.4
5	66.7	70.5	98.5
6	69.3	69.7	96.7
7	64.7	68.2	98.6

Analysis Table 2 shows that the methods used in screening the characteristics and risk factors of sports injuries in male college football players, as well as the effects of fatigue on the biomechanical characteristics of lower limbs in badminton players' stepping movements, have a mean degree of agreement with the actual situation of 69.6 and 73.73, respectively, indicating poor accuracy in the analysis. The average consistency between the analysis results of the fatigue characteristics of the inner and outer forearm muscles of athletes based on surface electromyography and the actual situation is 98.3, indicating that this method effectively improves the accuracy of analysis by using time-domain and frequency-domain related parameters in surface electromyography research as the basis for analyzing the fatigue characteristics of the inner and outer forearm muscles of athletes.

5. CONCLUSION

The author proposes a study on the electromyographic characteristics of the inner and outer forearm muscles in the basic movements of Tai Chi. Tai Chi athletes who train under various loads for a long time are prone to fatigue of the forearm muscles, which can lead to chronic injuries over time. In response to the existing problems in current related research, the author proposes a method for analyzing the fatigue characteristics of muscle groups such as the inner and outer forearms of Tai Chi athletes based on surface electromyography. By collecting electromyographic signals and conducting time-domain and frequency-domain studies, the fatigue characteristics of muscle groups such as the inner and outer forearms of Tai Chi athletes were analyzed. This research method outperforms current methods in terms of analysis accuracy and energy consumption, laying a foundation for

research in this field. The inner and outer muscles of the forearm are only a part of the body of Tai Chi athletes. The next step is to analyze the fatigue characteristics of other parts of the body of Tai Chi athletes; Surface electromyography is one of the most efficient methods for analyzing the fatigue characteristics of the body. The next step is to use different methods to analyze the fatigue characteristics of different parts of the body of Tai Chi athletes, in order to broaden the research scope in this field.

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REFERENCES

[1] Liu, H. H. , Nichols, C. , & Zhang, H. . (2023). Understanding yin-yang philosophic concept behind tai chi practice. Holistic Nursing Practice, 37(5), 75-82.

[2] Jiang, J. , Lv, J. , & Khan, M. B. . (2023). Visual analysis of knowledge graph based on fuzzy sets in chinese martial arts routines. aims mathematics, 8(8), 18491-18511.

[3] Kang, N. , Wang, Y. , Chen, G. , Guo, C. , Zhang, Z. , & Mei, D. , et al. (2022). Functional outcomes of tai chi exercise prescription in women with knee osteoarthritis. Sports medicine and health science, 4(4), 239-244.

[4] Hu, Y. , He, M. , Zhao, J. , Bishnoi, A. , Ziegelman, L. , & Hsiao-Wecksler, E. , et al. (2022). Effect of tai chi on resting state alpha power and functional connectivity in older women. Medicine & Science in Sports & Exercise, 54(9S), 596-597.

[5] Lyu, S. , Chen, Z. , & Meize CuiQiuyang WeiYameng LiHui FangMingyu LiuLinli LiuJiahao FuJianwei Zhang. (2023). Effectiveness of an online/offline mixed-mode tai chi cardiac rehabilitation program on microcirculation in patients with coronary artery disease: a randomized controlled study. Clinical hemorheology and microcirculation, 85(4), 385-393.

[6] Liu, J. , Guo, X. , Liu, S. , & Ran, J. . (2022). Tai chi softball improves inflammatory factors in overweight and obese female college students. Medicine & Science in Sports & Exercise, 54(9S), 513-513.

[7] Yang, Y. , & Xue, J. . (2022). The effects of 16-week tai chi course on the college students body composition. Medicine & Science in Sports & Exercise, 54(9S), 501-502.

[8] Shen, P. , Song, Q. , Li, L. I. , & Mao, D. . (2022). Effects tai chi on ankle strength and postural stability among older adults with sensory loss. Medicine & Science in Sports & Exercise, 54(9S), 296-297.

[9] Ryu, S. , Chen, Y. , & Gao, Z. . (2022). Effects of a tai chi app on mental health among breast cancer survivors. Medicine & Science in Sports & Exercise, 54(9S), 301-301.

[10] Croom, A. M. . (2023). The physiological and morphological benefits of shadowboxing. International Journal of Physical Education, Fitness and Sports, 54(9S), 611-611.

[11] Croom, A. M. . (2023). The impact of shadowboxing on the psychological well - being of professional martial artists. Discover Psychology, 20(26), 1-7.

[12] Yu - ichi Noto, Kitaoji, T. , Watanabe, K. , & Mizuno, T. . (2023). Assessment of motor unit firing by high - density surface electromyography detects motor neuronal hyperexcitable state in amyotrophic lateral sclerosis. Muscle and Nerve, 23(1), 351.

[13] Nguyen, C. , Kaufman, M. , Vallejo, A. , Deparis, S. , Friedlander, A. , & Frehlich, L. , et al. (2024). Analysis of common exercise modalities in improving athletic performance in older adults: a narrative review. Current Sports Medicine Reports, 23(6), 245-252.

[14] Wang, C. , Liang, J. , Si, Y. , Li, Z. , & Lu, A. . (2022). The effectiveness of traditional chinese medicine-based exercise on physical performance, balance and muscle strength among older adults: a systematic review with meta-analysis. Aging Clinical and Experimental Research, 34(4), 725-740.

[15] Fu, J. , Liu, C. , & Li, Z. . (2022). Research on the relevant effects of taijiquan exercise on the changes of lower limb muscle strength in the elderly based on nano biometric ic technology. International Journal of Nanotechnology, 19(6/11), 970-982.

[16] Avdan, G. , Onal, S. , & Smith, B. K. . (2023). Normalization of emg signals: optimal mvc positions for the lower limb muscle groups in healthy subjects. Journal of Medical and Biological Engineering, 43(2), 195-202.

[17] Vigotsky, A. D. , Halperin, I. , Trajano, G. S. , & Vieira, T. M. . (2022). Longing for a longitudinal proxy: acutely measured surface emg amplitude is not a validated predictor of muscle hypertrophy. Sports Medicine, 52(2), 193-199.

[18] Daniel, N. , & Maachowski, J. . (2023). Wavelet analysis of the emg signal to assess muscle fatiguein the lower extremities during symmetric movementon a rowing ergometer. Acta of Bioengineering and Biomechanics, 25(2), 15-27.

[19]Váczi, Márk, Fazekas, Gábor, Pilissy, Tamás, Cselkó, Alexandra, Trzaskoma, L. , & Sebesi, Balázs, et al. (2022). The effects of eccentric hamstring exercise training in young female handball players. European Journal of Applied Physiology, 122(4), 955-964.

[20] Wang, Z. I. , & Zhao, M. . (2023). Analysis of volleyball players' force generationduring jump spike from the perspectiveof electromyographic characteristics. Acta of Bioengineering and Biomechanics, 25(2), 147-155.