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Optimization of hand position on the bar for strengthening biceps brachii and latissimus dorsi during strength training

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Abstract

Purpose

Pronated or supinated hand positions during strength training on the bar can affect the muscle biomechanics of the entire upper limb and shoulder girdle Understanding these relationships can help improve sports training strategies and the process of physical therapy after injuries. The aim of this study was to optimize the hand position on the bar to identify the best biomechanical movement pattern and strengthen selected muscles during strength training.

Methods

A total of 31 students, 12 male and 19 female, aged 18-26 years, participated in the study. Each participant performed 4 series of bar pulls: 2 times in the pronated grip position and 2 times in the supinated grip position, at two different angles of arm opening. During the intervention, sEMG examination of the biceps brachii and latissimus dorsi was performed.

Results

Significant differences were shown during strength training for the biceps bra-chii in the hand grip position ($p<0.001$). All the observed showed an average increase in bioelectric activity of the tested muscles in the hand grip, regardless of the angle of the arm position.

Conclusions

Strength exercises of the biceps brachii in the hand grip on the bar may be analternative to milder strength training. On the other hand, training exercises in the grip require greater involvement of the biceps brachii and the latissimus dorsi. Surface electromyography precisely shows differences in the bioactivity of the upper limb muscles in the hand grip and undergrip during strength training, which confirms its diagnostic usefulness.

Keywords

resistance training, biceps brachii, muscle biomechanics, hand grip position, latissimus dorsi

1. Introduction

In recent years, there has been an intensive development of strength training, which is the focus of many researchers. This development is related not only to the desire to achieve higher levels of training, to search for tolerance and limits for physical effort, but also aims to understand the body's adaptation mechanisms to training stimuli. In scientific research, it has become important to analyze the changes brought about by strength training. It has been noticed that it is important for both professional athletes, sports enthusiasts, and non-training people, including, as we believe, astronauts and elderly people for whom strength training is becoming an important element of health prevention. Strength training is crucial for the body's functions. On the one hand, strength training increases the volume and strength of muscles, on the other, in a broader context, it increases the overall endurance of the body, improves health and quality of life. [5,12,23,27] Among training methods, we can distinguish, among others, dynamic and isometric strength exercises. However, it is important that strength training is properly adapted to the goals and characteristics of the exerciser. Systematic adjustment of training intensity, resistance, tempo, and number of repetitions is crucial for achieving optimal results and is specific to a given group of exercisers. [3,5,8,15,16,22] Appropriate adaptation of the body to strength training is necessary to avoid overload and injuries. The type of strength training is of particular importance due to the sports discipline being trained. Achieving higher sports results requires the adjustment of different strength exercises for sports where a large external resistance is overcome, e.g. bodybuilding, and strength-endurance sports, e.g. volleyball, climbing. [3,9,15,16,22,29]

It is widely believed that strength and endurance training play an effective role in building the condition of the muscles of the shoulder girdle and upper limbs. This type of training has a positive effect on both increasing the mass and strength of the trained muscles and additionally plays a key role in the process of rehabilitation after injuries and as part of preventive measures. [5-7,12] Many sports disciplines require a strong shoulder girdle and high endurance of the upper limbs. In order to achieve the intended effects, it is necessary to conduct optimized fitness training that increases the strength and muscle mass of these structures. At the same time, participation in sports competitions increases the number of injuries and contusions in the discussed muscle groups among athletes, which leads to the search for new and easy, and above all non-invasive diagnostic methods, and then corrected training programs and optimal ways of rehabilitation, allowing for a quick return to sports. Disciplines that engage the upper body muscles include sports climbing, American football, basketball, handball, volleyball, tennis, rowing, and bodybuilding. Many typical activities, such as serving, throwing, hitting, driving, blocking, attacking, and pulling, require good physical conditioning. [2,3,9,10,16,24,28] Education on properly conducted strength training and simple ways to implement it in everyday life can help develop good exercise habits in both training athletes and patients working on increasing strength and functional fitness.

An important topic is therefore the correct execution of training and paying attention to specific muscles that are directly engaged in it. The interdependence between the myofascial and kinematic systems is important here. Their mutual cooperation creates an inseparable whole and is necessary for adaptation during strength training. In the case of strengthening the shoulder girdle muscles due to improper strength training and work in the wrong functional position of the upper limbs, the risk of muscle overload in this area increases. From this perspective, the correct interaction within the biokinematic chain is very important. This means that a disturbance in any of the links of the upper limb and shoulder girdle brings with it an avalanche of changes [1]. Proximal disorders, closer to the shoulder girdle, may affect the insufficiency of distally located sections, for example in the area of the hand and its grip. Disturbances of intersegmental coordination may result from poor movement speed, improper posture for strength training or the positioning of the upper limbs. Improper training has a negative impact on movement patterns, can lead to movement kinematics disorders or upper limb injuries. Incorrectly performed strength exercises may also not bring the desired training or therapeutic effects. Striving to improve strength training procedures, searching for new forms of research, in order to avoid ineffective exercises and replace them with desirable ones should be a current need of researchers and trainers.

Transcutaneous electromyography (sEMG) is often used in studies on the optimization of strength training. SEMG is a common, non-invasive tool that allows for the accurate analysis of muscle bioelectrical activity, which is necessary to monitor the effectiveness of training. Physically, this method refers to the examination of skeletal muscles using electrodes attached to the skin, while maintaining its continuity. SEMG is used in various fields of medicine, including neurology, orthopedics, physiotherapy, and sports medicine. Surface electromyography is useful for assessing the size, duration, and pattern of electrical activity in the muscles of the limbs and trunk, which allows researchers to accurately analyze the state of the motor and nervous systems [13]. In addition, sEMG can be used to monitor the progress of physiotherapy and rehabilitation of patients after dysfunctions, injuries, immobilizations, and various orthopedic procedures that resulted in weakened muscle strength. The study allows for accurate tracking of changes in the activity of selected muscles during and after therapy. [13,18]

In the context of sports research, electromyography is used to assess muscle performance, identify areas of potential injury risk, and optimize sports training. Analysis of muscle activity using sEMG allows trainers and physiotherapists to tailor training programs to the individual needs of athletes, which can help improve sports performance and prevent injuries [13]. It has been shown that appropriately selected strength training promotes significant increases in skeletal muscle mass. Some programs will induce greater muscle activity than others and therefore lead to hypertrophy over time, but this is associated with adaptation depending on the specific stimulus [25]. However, there is still a lack of research on the best combination of hand positioning on the bar to optimize the increase in muscle mass of the shoulder girdle and upper limb and not to overload them in the event of weakness.

The work was undertaken to analyze the work of the biceps brachii and latissimus dorsi during shoulder girdle exercises on the high pulley depending on the hand position. Weakening of the biceps brachii can be caused by many diseases and injuries and can also occur as a result of necessary immobilization for therapeutic purposes. Such a situation always results in limited upper limb function. Similar effects are brought about by weakening of the latissimus dorsi muscle, although they concern the shoulder girdle itself more and occur less often. In each case, after the dysfunction, a process of strengthening and functional improvement of the limb will be necessary to restore the patient to the fullest possible fitness. sEMG examination was used to determine in what hand position during the exercise on the "high pulley" the activity of the biceps brachii shows the highest values. This may allow for indicating the optimal position for an exercise increasing the strength and mass of this muscle in a physiotherapy session or sports strength training. Additionally, since this exercise also activates the trunk muscles, the test will allow us to determine whether a similar situation occurs with the latissimus dorsi muscle, which is indirectly related to the efficiency of the shoulder girdle and the upper limb.

The aim of the study was to optimize the position of the hands on the bar in order to strengthen the biceps brachii and latissimus dorsi muscles during strength training based on sEMG recording. The secondary aim was to assess the usefulness of sEMG in assessing the effect of hand position on the bioactivity of selected muscles during strength training.

2. Materials and Methods

Study Population

The study participants consisted of 31 volunteers aged 18 to 26 (mean 23.7±1.7), including 12 men and 19 women, recruited from the student population of the Jagiellonian University Medical College in Krakow. All of them were recruited from physical education classes, with no contraindications to high pulley exercises and no current or recent (≤ 6 months) injuries or dysfunctions of the muscles being tested. Only students who expressed a voluntary willingness to participate in the study were qualified for the study. Of the 35 people who registered, four participants did not take part in the study (1 due to injury, 1 due to lack of time, 2 due to personal reasons).

Methods

The study was conducted at the Department of Physiotherapy, Faculty of Health Sciences, Institute of Physiotherapy, Jagiellonian University. All procedures were performed in compliance with relevant laws and institutional guidelines and have been approved by the appropriate institutional committee. The consent of the Bioethics Committee to conduct the study was obtained (no. 118.6120.199.2023 dated 29.02.2024). The publication of the image of the person depicted in the photographs is subject to their prior written consent, in accordance with the principles of research ethics. All procedures were conducted in accordance with the Helsinki Declaration regarding research on humans. The exclusion criteria there were: lack of participant consent, age outside the 18-26 range, current or past (within 6 months) injury or dysfunction of the examined muscle. Informed consent was obtained from all participants before the start of the study.

The research tools there were: upper pulley with a bar, sEMG, Noraxon Ultium EMG software, surface electrodes and sensors.

The sEMG examination was performed using the Noraxon Ultium EMG device and software, which is part of the equipment of the CDT CARD UJ CM Laboratory. The sEMG examination procedure was conducted in accordance with standard recommendations for this type of examination. The examination used superficial electrodes, gelled with silver chloride, recommended by SENIAM. The electrodes were disposable with a diameter (conduction area) of 1 cm. [11,14]

Ultium EMG sensors were used to collect data on the degree of muscle activation next to surface electrodes, which offered sampling up to 4000 Hz, real-time synchronization, and very low base noise (<1 μV RMS) with minimal artifacts [20].

Muscles tested

The biceps brachii muscle is one of the most important muscles of the upper limb. Its main role is: flexion at the elbow joint, and additionally participation in flexion at the shoulder joint. In addition, the long head abducts and rotates inward, and the short head adducts at this joint; at the elbow joint, the entire muscle additionally supinates the forearm and tightens the forearm fascia [30].

The latissimus dorsi muscle is attached to the spinous processes of the Th5 or Th6 vertebrae to Th12, L1-5 and the median sacral crest, the posterior 1/3 of the external lip of the iliac crest, and to the external surface of the IX or X-XII rib, making it a muscle that is part of the trunk muscles. The distal attachment is located on the crest of the lesser tubercle of the humerus, so the muscle's activity also concerns the shoulder girdle. It adducts, extends and rotates the arm inwards, and is also an auxiliary expiratory muscle [30].

Training Procedures

First, the student was taped with electrodes. Surface electrodes were placed on the bellies of the biceps brachii and latissimus dorsi muscles. Then, as a reminder and visualization, the researcher showed the bar pulling movements that would be required during the test. The student was prepared for the pulley test. The student's starting position was sitting with a straight back, the bar was mounted at an individually adjustable height at the level of the arms stretched upwards.

The student's work consisted of pulling the bar down to the height of the shoulder girdle in two different hand positions - overhand grip (pronation position) and underhand grip (supination position) and in two angular settings of the arm opening: I. 90° measured between the transverse axis of the arms (shoulder girdle) and the entire upper limb, flexed to 180° at the shoulder joint; and II. 135° measured between the transverse axis of the arms (shoulder girdle) and the upper limb flexed to approximately 180° and abducted to 45° in the shoulder joint.
The research positions are presented in the figures below: 1,2,3.

Fig. 1 Muscle testing on the upper pulley, hands in pronated grip.

Fig. 2 Muscle testing on the upper pulley, hands in supinated grip.

Fig. 3 Muscle testing on the upper pulley with an applied angle of abduction.

Then, 4 series of pulls on the upper pulley were performed, including 2 times with a hand grip and twice with a hand undergrip, with the arms simultaneously positioned in two positions. The first position of the arm position was for an angle of 90°, and the second position for an angle of 135°.

Statistical Analysis

The results were developed using the SPSS statistical program, using the Shapiro Wilk test to examine the distribution and the T-student and Wilcoxon tests to check statistical significance. The level of statistical significance was assumed to be α=0.05.

3. Results

The following results were obtained from the conducted study:

3.1. Supination - arm position 90° and 135°

3.1.1. Biceps brachii

The average of all measurements of biceps muscle activity for the arm position called 90° underhand grip in the entire group of subjects was 73.2 μV; for the 135° underhand grip position 62.3 μV.

3.1.2. Latissimus dorsi

The average of all measurements of latissimus dorsi muscle activity for the arm position called 90° underhand grip was 64.9 μV; for 135° setting with subgrip 44.0 μV.

3.2. Pronation - arm position 90° and 135°

3.2.1. Biceps brachii

In the overhand grip position with arms at 90° for the biceps brachii, the average activity for the entire group was 56.0 μV; in the arm position of 135° it was 50.3 μV.

3.2.2. Latissimus dorsi

For the latissimus dorsi in the overhand grip position with arms at 90°, the average activity was 40.1 μV; in the arm position of 135° it was 45.2 μV.

The result of the parametric t-Student test in both cases of the angular position of the arms indicated the statistical significance of the analyzed mean values ($p < 0.001$) for greater average activity of the biceps brachii in the underhand grip position compared to the overhand grip position.

For the latissimus dorsi muscle, although in many cases the activity results in the underhand grip were also higher than in the overhand grip, statistical significance was not achieved for the entire sample ($p > 0.001$).

The obtained results are presented in Table 1.

Table 1. Summary of the results of average muscle activity depending on the hand position and the angle of arm opening measured in μV.

mean / muscle	pronated hand positions 90°	supinated hand positions 90°	pronated hand positions 135°	supinated hand positions 135°
BB	56,03	73,21	50,37	62,35
LD	40,19	64,94	45,21	44,00

Abbreviations: BB-biceps brachii muscle, LD-latissimus dorsi muscle,[μV]

4. Discussion

The influence of pronation and supination of the hands on the tested muscles – optimization of strength training

In this study, the importance of the position of the hands in supination and pronation during the pull-up bar for the biceps brachii and latissimus dorsi was confirmed. We find that high activation of these muscles during the underhand grip suggests more efficient training in this position, especially when aiming for hypertrophy, but on the other hand it indicates the need to prepare the indicated muscles for exercises in this position in the event of their weakening after injury.

In the work of Lusk et al. [17], the influence of the position of the upper limbs on 3 muscles included in the shoulder girdle was examined: biceps brachii, trapezius and latissimus dorsi. It was found that the width of the arm position (wide or narrow) does not cause statistically significant changes in the degree of activity of the mentioned muscles, but it was proven that the type of grip used has such an influence. In this case, it was shown that the overhand grip resulted in greater activity of the latissimus dorsi muscle than the underhand grip, both with a narrow and a wider arm position. [17] Similarly, the influence of the position of the upper limbs during exercise was studied by another research team, Signorille et al. [26]. It was found that the activity of the latissimus dorsi muscle was higher in the 135° overhand grip than in the 90° underhand grip.

Both studies focused mainly on the latissimus dorsi muscle; however, both showed that the position of the limbs has an impact on the activation of the desired muscle. [17,26] In this study, statistically significant results were not obtained with respect to the latissimus muscle, however, based on sEMG, the influence of the position of the hand during strength training on the high pulley on the biceps brachii muscle was proven. The goal was to check what could result in its greater activation during exercises and it was noted that it is the position of the hand in the underhand grip. The difficulty in relating the obtained results turned out to be the questionable quality and small number of scientific studies conducted so far related to the subject of the study.

Additionally, which seemed obvious to draw attention, our analysis assesses the usefulness and reliability of sEMG for assessing the activity of muscles affecting the shoulder girdle in tests on the high pulley. We confirm that sEMG is an extremely precise method that allows for monitoring and analysis of the electrical activity of the biceps brachii and latissimus dorsi muscles.

Usefulness of sEMG in strength training

Currently, an increasing number of research tools enable functional diagnostics and optimization of training plans depending on the adopted assumptions. One of them is electromyography, a diagnostic technique that plays a key role in the study of bioelectrical muscle activity.

The study of muscle bioelectrical activity using sEMG has recently become a very useful research and diagnostic element in the work of a physiotherapist due to its lack of invasiveness [19]. It allows for direct assessment of: how and to what extent a muscle is activated during a specific movement. This is an extremely important element of rehabilitation, as it confirms the assumption that the required muscle is actually activated. It can also be a helpful tool in assessing the progress of therapy.

Electromyography allows for understanding the functioning of the neuromuscular system and identifying muscle and nervous pathologies and disorders related to them. Due to its accuracy and versatility, EMG is irreplaceable in the process of diagnosing and treating many diseases (neuropathies, muscle inflammations, degenerative diseases of the musculoskeletal system) and in supporting the process of rehabilitation and sports training. [18]

There are many reports in the medical literature on elementary electromyography (eEMG), performed according to strictly established standards, which, together with electroneurography, is used as a complementary diagnostic test in many neuromuscular diseases. Much fewer scientific reports concern surface electromyography (sEMG), which is a valuable source of information on the functional assessment of the patient's muscles for orthopedic and physiotherapy purposes [21]. The use of surface electromyography techniques in both practice and scientific research can have a positive impact on the development of knowledge in the field of orthopedics and physiotherapy. They can be used to verify the usefulness of various therapeutic methods, exercises and clinical tests used by orthopedists and physiotherapists, and therefore should be included in the topics of highly specialized training for these professional groups [4]. The present study confirmed that this method can be used to optimize sports training, develop a precise methodology for performing exercises that improve, increase the strength and mass of selected muscles, e.g. those affected by post-traumatic or post-operative dysfunction.

Trainers can more precisely select the hand position depending on training goals. By identifying differences in muscle activity in different hand positions, trainers and physiotherapists can design programs that take into account different intensities and loads, according to the goals (strength, endurance, improvement exercises). Knowing which hand position activates specific muscles can help exercisers and trainers avoid overloads and injuries, and physiotherapists create more personalized rehabilitation programs.

Strengths and weaknesses of the study

Based on the presented results, it can be concluded that the position of the hand, but also the entire upper limbs, can affect the activity of selected muscles of the upper limb - in the studied case, on the activation of the biceps brachii muscle, and such an assessment can be made based on the sEMG study.

The strengths of the study are the similar age and physically fit group of participants and the sensitivity and reliability of the sEMG tool. In addition, we have not encountered an sEMG assessment of the biceps brachii and latissimus dorsi with different combinations (pronation, supination) of the position of the hand on the bar. The sEMG study clearly showed a difference in the activation of the biceps brachii and latissimus dorsi muscles in different hand positions, which suggests that it can also be used successfully in relation to other muscle groups of the upper limb. An undoubted advantage is the resulting "recipe" on how to optimally maximize the growth of the shoulder girdle and upper limb muscles by strength training, paying attention to the pronation or reversal of the hand. When looking for weaknesses in the study, one can consider creating a more homogeneous group in terms of gender in the next study. Currently, the study included both women and men - which could, due to the characteristic anatomical structure, slightly different between men and women in relation to the trunk muscle, result in a greater discrepancy in the results in relation to the latissimus dorsi muscle. This requires further research divided by gender. It is also worth conducting similar studies in a homogeneous age group after surgery or dysfunction, in a situation where there is a need to activate and strengthen the aforementioned muscles. It may also be interesting to examine the remaining muscles of the shoulder girdle, engaged in work in sports disciplines, and to find optimal positions for them for fitness exercises. The value of muscle bioactivity itself may vary depending on the groups studied in the adult and age-group sports and amateur and community games.

A key contribution of this study is the comparison of muscle activity between two grip types (pronated and supinated) using surface electromyography (sEMG), combined with a simultaneous analysis of two shoulder joint abduction angles. The results indicate a relationship between grip type and training intensity. The findings suggest that the supinated grip may serve as an alternative for lower-intensity strength training.

Practical Implications

Overhand and underhand training have a beneficial effect on increased muscle activity, but underhand training is better at increasing the strength of the biceps brachii.

In summary, underhand training seems to induce greater bioelectrical muscle activity at different arm openings, depending on the muscle being tested, and surface electromyography is a useful diagnostic and monitoring tool for muscle activity affecting the shoulder girdle.

The obtained results are the basis for further research on the interactions between muscles and joints of the upper limb. Thanks to this research, it will be possible to develop more advanced training or physiotherapy methods and devices for monitoring and optimizing training efficiency.

5. Conclusions

The position of the upper limbs during high pulley exercises affects the degree of activation of selected muscles of the shoulder girdle, which is worth considering in conditioning training of these muscles. The biceps brachii shows significantly greater activity during high pulley exercises in the underhand grip position compared to the overhand grip. For the latissimus dorsi muscle, in most cases higher activity results were obtained in the under grip than in the over grip, for an arm angle of 90°, however, statistical significance was not obtained for the entire sample. Surface electromyography is a reliable diagnostic tool for assessing the bioactivity of selected muscles, which is why it can be used in planning sports training and in the process of motor improvement after injuries.

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