

Influence of hand grip in resistance-training exercises on the triceps brachii activation: A narrative review

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Abstract

Introduction: When you perform an exercise to only one joint of your body, a change in the axis line can have significant effects on the extent that agonist muscle is activated. In this review, the authors critically present an analysis of potential injury risks by certain triceps brachii exercises. Hand positioning (pronation/supination) was suggested to influence activation of the long, medial and lateral heads of the Triceps Brachii. Yet, assessing the medial head activation with surface electromyography is still impossible as it cannot be recorded because of its anatomical situation. Secondly, some exercises can strain or damage passive tissues that are hard to be felt and thus will not alarm the exception but may deteriorate as time goes by until an injury is generated. **Materials and Methods:** The aim of this review to illustrate beneficial and contrary hand position changes, during different triceps brachii exercises with appropriate health aspects. This type of analysis aims to maximize congruence and coaxial alignment across joints, taking into account any overloading effects on certain ligaments which could potentially increase injury risk. **Results:** There is currently limited evidence in the literature supporting that one grip hand (pronated or supinated) target certain heads of the triceps brachii either more than other heads. However, a neutral hand grip might reduce injury risk and provide the most stability. As a result this positioning might additionally have advantage **Conclusions:** The single-joint triceps brachii strengthening exercises were categorized into three levels (good, moderate to good and poor) according joint safety and efficacy in this review. Nevertheless, the analysis did not account for stretch placement through exercises which may have stronger potential to increase hypertrophy.

Keywords: Strength training; exercise movement techniques; muscle strength; musculoskeletal pain; muscle hypertrophy; sports injury

Introduction

Resistance training in the upper limb is organized using push-and-pull exercises (Vargas et al., 2019). Pushing exercises mainly involve the pectoralis major, deltoids in its clavicular portion, and triceps brachii (TB), as these exercises approach and move away dynamically and in unison, acting as agonists or synergists (Gottlob, 2008). Although there are several studies on the involvement of these muscles in trunk movements (e.g., bench press) (Lauver, Cayot, & Scheuermann, 2016; Rodríguez-Ridao, Antequera-Vique, Martín-Fuentes, & Muyor, 2020; Saeterbakken, Mo, Scott, & Andersen, 2017), few have focused on single-joint exercises. The single-joint push exercise involves elbow extension, in which the agonist muscle is the TB. Anatomically, the TB has three clearly differentiated fascicles: medial, lateral, and long heads (A. Ali et al., 2015), which can function independently (Madsen et al., 2006).

The influence of different angles of the shoulder and elbow joints on the ability of the TB to produce an extension moment of the shoulder joint has also been investigated (Landin & Thompson, 2011). In this regard, the surface electrical activity of musculoskeletal tissue (sEMG) and inverse kinematics are used to assess the functional capacity of the three heads by comparing muscle strength and activity at various angles of shoulder flexion (Kholinne et al., 2018). Moreover, differences in cognitive stress have been observed between the heads of the triceps (Hussain, Sundaraj, & Subramaniam, 2020). Furthermore, functional activities associated with activities of daily life involve the medial, lateral, and long heads (Srinath, Corey, Nitz, & Uhl, 2015). Although the three heads have different functions and can be activated more intensely depending on the movement

performed (they can be targeted individually), the three triceps muscle are involved (although activation levels vary) during elbow extension (Hussain, Sundaraj, Subramaniam, & Lam, 2020).

Certain beliefs derived from traditional body building have been assumed when the aim is to optimize TB activation and muscle hypertrophy. For example, it has been proposed that i) higher activation of the TB lateral head is reached when the thumb points upward (neutral grip), ii) more emphasis is placed on the long head through the internal part of the triceps with a pronate grip, and iii) supine grip will evoke higher activation of the medial head (Schwarzenegger, 1992). The only investigation to our knowledge is the one proposed by Villalba et al. (2024), where they evaluated the hand position, prone or supine with two different handles, handle vs. standard padded pulley strap, on the long and lateral head. In this case, there was more electrical activity with the supine hand for the long head. However, with the pronated position there were no significant differences.

Subsequently, Professor Tesch (2001) applied nuclear magnetic resonance to analyze the contribution of the different TB heads to the main exercises. In the book describing the results, neither the sample nor the methodology is described, but for this review, it is emphasized that with neutral grip and shoulder flexion intense muscular implications are obtained (as defined in his original text) (Tesch, 2001, page 80). In his compilation he includes overhead triceps extension with reverse grip in which the lateral and medial head only obtain the rating of moderate muscle involvement. In another inverted grip exercise, the unilateral pulley pulldowns do show intense muscle activity in all heads (Tesch, 2001).

However, scientific evidence focused on TB muscle activity in different variants of exercise movement remains limited and is even less regarding the hand position when performing different exercises. While sEMG has been studied in relation to supination and pronation in the elbow flexors (Naito et al., 1995) or forearm musculature (Bader et al., 2018; Gordon, Pardo, Johnson, King, & Miller, 2004), there is limited research to date evaluating sEMG in the different variations used in TB exercises. The aim of this review was to explore whether the position of the hand in single-joint exercises for TB can generate more risks than benefits when the objective is to focus on a certain head.

Functional anatomy and performance

Joint physiology distinguishes two different functions in the elbow joint: a) pronation-supination, which affects the superior radioulnar joint, and b) flexion-extension through the humerus-ulnar and humerus-radial. In flexion, the biceps brachii, brachialis, and brachioradialis are mainly involved and in extension the TB is the main component (Kapandji, 2006). Furthermore, elbow extension is minimally reinforced by the anconeus (Tortora, 2005).

The lateral head of TB originates on the posterior side of the humerus, proximal two-thirds of the lateral brachial intermuscular septum, and the medial head on the posterior side of the humerus on the medial brachial intermuscular septum (Putz & Pabst, 2000). The long head of the TB originates from the infraglenoid tubercle of the scapula, whereas the three heads are inserted into the olecranon. However, the fibers of the long head run longitudinally, whereas those of the medial and lateral heads run obliquely (Soubeyrand et al., 2017). The difference in origin affects functionality; while the three heads act as elbow extensors, the long head additionally acts on the scapula, bringing the shoulder closer (Boeckh-Behrens & Buskies, 2005). Moreover, the shoulder acts as a third-class lever, with the strength applied between the joint axis and the load (Salmons, 1995).

Current research on TB focuses on muscle length, shoulder position, and the degree of elbow flexion to provide more targeted work on specific portions of the muscle. The position of the elbows and shoulders can affect the activation of the long head owing to its origin, whereas the medial and lateral heads would only be influenced by the degree of elbow angulation (Davidson & Rice, 2010). The origin of the long head affects shoulder flexion, with the maximum point of flexion resulting in the greatest head length (Landin & Thompson, 2011). Alves et al. proposed that long headwork is preferred at the highest point of elongation (Alves, Matta, & Oliveira, 2018). Vogt and Hoppeler suggested that training strength from different fascicle lengths would strengthen the muscles to work in various areas of the length-tension relationship (Vogt & Hoppeler, 2014).

Recently, it has been suggested that 180-degree glenohumeral flexion achieved with overhead elbow extension exercise leads to greater hypertrophy than the neutral version (0° shoulder flexion), indicating that the greater the length of the muscle separating the two involved joints, the more hypertrophy is obtained (Maeo et al., 2023). However, Kholinne et al. found that at 0° shoulder flexion the long head generated more strength and sEMG, with no differences between the lateral and medial head, contradicting previous proposals (Kholinne et al., 2018). At 90° shoulder elevation, the medial head generated more strength and sEMG without differences between the other two, and at 180°, the lateral head provided more strength and sEMG. All the heads of the TB generated more strength and sEMG when the elbow was flexed at 90°, and the TB was more effective when the elbow was flexed between 20° and 30°.

Regarding the position of the elbow, Murray et al. found activation throughout the extension range of motion in the long and lateral heads (Murray, Buchanan, & Delp, 2000), whereas the medial head has been shown to be more activated when the elbow is flexed (Madsen et al., 2006). TB is more effective when the elbow is flexed between 20 and 30°, as the TB tendon wraps around the upper surface of the olecranon and acts as a pulley (Nigel, Roger, & Field, 2000).

Functional anatomy and joint health

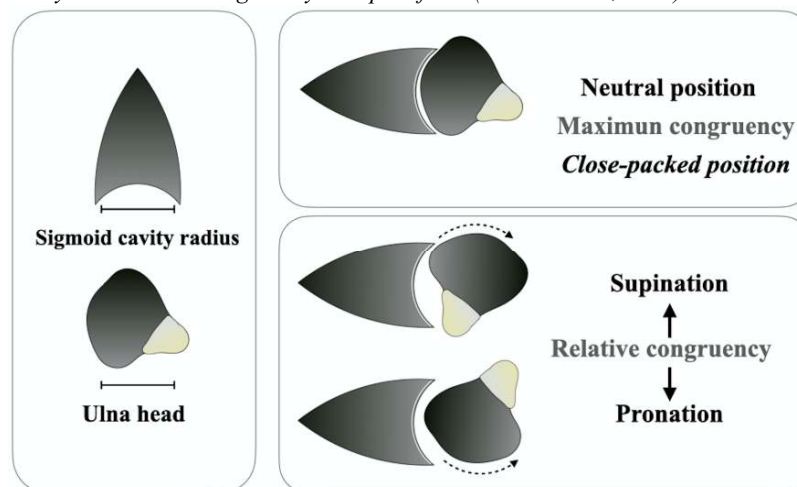
In addition to its effect on performance, it is worth noting that supination or pronation can also impact joints. Prono-supination refers to the movement of the forearm around its longitudinal axis and requires the intervention of two joints: the proximal radius-ulnar joint and ulnar-distal radius joint (Perotto, 2011). When performing supination or pronation, there is a lack of geometric agreement between the articular surfaces in the radial ulnar-distal joint, resulting in relative incongruence. This means that the head of the ulna does not fully fit the sigmoid cavity of the radius, leading to reduced joint stability. At maximum pronation, the ulnar head may even partially dislocate posteriorly, with only the posterior radioulnar ligament providing support (Soubeyrand et al., 2017). Additionally, in both maximum pronation and supination, the triangular ligament is partially distended, and the anterior and posterior ligaments of the distal radioulnar joint do not stabilize the joint or limit movement.

The rotation range of the forearm is approximately 90° in pronation and supination, with neutral rotation (thumb parallel to the humerus) considered as 0° (Soubeyrand et al., 2017). Soft tissues, such as the interosseous membrane anterior bundle and squared ligament, limit supination, whereas the radioulnar abutment restricts pronation in extreme cases (Soubeyrand et al., 2017). Repetitive work with high loads in pronation or maximum supination can compromise these structures (Bonilla et al., 2022).

It is important to note that the distal and proximal radioulnar joints function as a single mechanism, known as coaxial joints (Roman-Liu & Bartuzi, 2018). This means that the axis of one joint must be a continuation of the other, and the maximum degree of stability for both joints is achieved in the neutral position. This position is called the close-packed position, or maximum congruency, where the joint is most comfortable and the ligaments work optimally (Kapandji, 2006) (see Fig. 1).

Figure 1

Maximum congruency and relative congruency. Adapted from (Srinath et al., 2015)



In mechanics, the concepts of balance and stability are closely related (Vera-García, Barbado, Moreno-Pérez, Hernández-Sánchez, & Juan-Recio, 2015). Pollock et al. defined balance as “the state of an object when the resultant force acting upon it is zero,” while stability refers to “the inherent ability of an object to remain in or return to a specific state of balance and not to fail, with the inherent ability referring to the physical properties of that object” (Pollock, Durward, Rowe, & Paul, 2000). A body is said to be in equilibrium when the sum of all the forces and moments of the forces acting on it is equal to zero (Bergmark, 1989). Thus, stability is the ability of an object to maintain its state of equilibrium in the face of both internal and external forces to which it is subjected (Elvira, 2008). Greater joint stability can compromise passive structures to a lesser extent and prevent unwanted movements, thereby reducing the risk of injury (Cardozo et al., 2021). Therefore, greater stability leads to better performance and a lower risk of injury (Bonilla et al., 2022).

Material and Methods

A narrative review was conducted using a convenience search due to the lack of studies evaluating hand position in triceps exercises. Only one recently published study has addressed this issue (Villalba et al., 2024). This narrative review allows for the inclusion of diverse views and theories in order to facilitate a more complete view that would not be achieved by quantifiable, or comparable means.

Exercises for triceps brachii strengthening

It has recently been concluded that exercises involving TB should be performed with full ROM to optimize muscle hypertrophy (Kassiano et al., 2023). However, a poor technical execution performing high-load

activities could involve an elbow extension and valgus, such as throwing or repetitive forces, the elements of stability may not be sufficient, leading to pathologies and structural failures (Zouzas, Byram, Shillingford, & Levine, 2012). Traditional TB exercises generally do not generate valgus, which can test the medial collateral ligament and lead to predictable injury patterns, as seen in tennis serve, baseball hit, and javelin throw (Zouzas et al., 2012). However, varus is more commonly caused by technical deficiencies in some TB exercises, and the lateral ulnar collateral ligament provides varus stability. Supination, axial compression, and a varus moment can cause posterolateral rotatory instability, which is observed in break dancers or gymnasts when they exert high forces on their elbows to support the entire body weight (Zouzas et al., 2012).

Lying triceps extensions

When performing resistance-training exercises, practitioners should be particularly mindful of exercises that place a high axial load on a joint, such as lying triceps extensions (also known as skullcrushers). In this exercise, it is common for the elbow to open and create a pronounced varus, which puts extra strain on the soft and bone tissues required for stability, especially when using high loads or experiencing fatigue. The addition of pronation to exercise would increase the demand for soft tissues to provide stability. Pronation moves the radius in front of the ulna, causing relative incongruity in the joint (Gordon et al., 2004). Although prono-supination is a natural movement for eating and other tasks (hygiene and climbing), it can cause excessive stress on joints and passive structures during analytical exercises for body building (Kapandji, 2006).

The triceps is a muscle that can generate high-power metrics (Hussain, Sundaraj, Subramaniam, et al., 2020), and it is common a fast load progression in this exercise that in many cases these loads will alter the correct exercise technique and therefore increase the risk of injury. Lying triceps extensions offers optimal performance results, leading to increased muscle cross-sectional area (Goto et al., 2017). However, there are no data on which hand position is the most favorable for working on a particular triceps head. For optimal joint stability and risk-to-benefit ratio, it is advisable to perform the exercise in a neutral position. This maximizes the joint congruence and minimizes the muscle expenditure. To achieve this, it is best to use a triceps bar or dumbbell in a neutral position. When using the traditional bar, it is important to note that the functional position for pronosupination is between the neutral position and semi-pronosupination (30-45° °pronation). This natural balance between antagonist muscle groups can be achieved using an e-z curl bar (Gordon et al., 2004). Performing elbow extensions over the head in pronation it is possible that this movement may increase tensile forces on the connective tissue that could pose a risk to these structures, making it more advisable to use a neutral position (Bonilla et al., 2022).

Cable resistance-training

There are various types of handles available to work on pulleys, such as triceps rope, short handles with rope, bar triceps v-ergo, and straight bars that favor supine and prone grips. The triceps rope and triceps v-ergo provide a more comfortable and ergonomic position, which is more functional between 30-45° of pronation. However, excessive stress can be generated by abusing the grip during supination or pronation with the straight grip. In a study by Rendos et al (Rendos et al., 2016), the influence of three different handle conditions was examined: standard handle, ball handle with a cable between the index and middle fingers, and ball handle with a cable between the middle and ring fingers. The assessment were performed with the hand in pronation, unfortunately there are no data available for the scope of this review (Rendos et al., 2016).

Triceps bench dips (bench dips)

The bench dip exercise is another movement that requires attention as it places the hand in a pronated position, adding stress to the distal radioulnar joint, while the elbow opens up. In contrast, triceps dips are a favorable option for TB because problems with elbow positioning are not usually encountered when the hands are positioned neutrally. Advanced participants could use an additional load as a ballast vest. However, it is important not to confuse the full range of movements with the exercise, as it could increase the risk of shoulder (glenohumeral) joint injury by closing the subacromial space. It is important to note that the bench press puts the hand in pronation, in addition, with axial load, but not all the weight falls on the elbow joint, since much of the work is carried by the shoulder girdle. On the other hand, parallel bottoms keep the upper limb in neutral position, so it can favor the load increase, as there is a maximum congruence. But, let's not confuse the articular health of the elbow with "lowering" too much in the bottoms, since it can close the sub-acromial space and increase the risk of injury. Moreover, no extra benefits have been observed in electrical activity when performed at 90° shoulder flexion or at full range (Boeckh-Behrens & Buskies, 2005).

Final considerations

There is little literature that addresses the analysis of sEMG during the different variants for triceps brachii strengthening, and the few that exist present a high degree of heterogeneity (table 1). The available data suggest that the degree of glenohumeral angulation may influence the degree of activation of the different TB

heads, but in general the levels of activation are similar. In the case of the degree of pronosupination, the studies carried out have been performed with isometric actions, so it is difficult to transfer it to dynamic actions. However, considering some muscle adaptation data such as those provided by the muscle adaptations are similar regardless of the exercise to be performed for TB, in women new to strength training who underwent a 6-week program (2 sessions/week) with unilateral cable push-downs and cable overhead extensions with the contralateral arm and cable overhead extensions with the contralateral arm.

In addition, although sEMG is considered the gold standard for non-invasively evaluating electrical activity at the muscle level, it is essential to note that obtaining entirely reliable data for evaluating the sEMG of the medial head using this technique is difficult. This is because the medial head was located beneath the other two heads, which can create noise. In this regard, SENIAM (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000) does not provide recommendations for sensor location in the medial head. Consequently, sEMG investigations in TB have evaluated the lateral, long head, or both simultaneously, because of the ease of locating and placing the electrodes (Akagi, Shikiba, Tanaka, & Takahashi, 2016; Alves et al., 2018; Rendos et al., 2016; Roman-Liu & Bartuzi, 2018), with some exceptions where the methodological information is confusing (A. Ali et al., 2015; Kholinne et al., 2018; Serrau et al., 2012) or nonexistent (M. A. Ali et al., 2014; Landin & Thompson, 2011) without specifying electrode placement. Conversely, some authors (Hussain, Sundaraj, & Subramaniam, 2020; Hussain, Sundaraj, Subramaniam, et al., 2020) identified and placed electrodes in the presence of a physician, as described by (Perotto, 2011) and following SENIAM. Therefore, sEMG does not appear reliable for evaluating the middle head of the TB.

The main findings of the included studies for this review can be found in Table 1.

Table 1

Summary of the studies included in this review using SEMG for triceps brachii analysis in strengthening exercises

Author	Sample	Exercise	Variations	sEMG location	Main results
Alves et al 2018	21 males 25.57±5.57 years, At least 12 months of resistance training experience	Elbow extension 1 repetition 40% MVIC	a) seated position with the right arm leaning against the chair's backrest, the elbow at 90° and forearm at neutral position b) seated position and right shoulder flexed at 180° c) lying on supine position and right shoulder flexed at 90°	Triceps brachii long and lateral heads according to SENIAM recommendations	Variations b and c obtained similar results
Ali et al., 2014	Thirteen sportsmen healthy male university students = 24.3 ± 4.1 years	Handgrip in neutral position of the upper limb with full extension of the forearm between abduction and adduction	Handgrip in neutral position of the upper limb with full extension of the forearm between abduction and adduction	Lateral, long, and medial heads of the TB of the dominant arm	Electromyographic activity changes are observed to be more significant at the long head as compared to the lateral and medial heads.
Hussaein et al., 2020	25 young, healthy, recreationally active 23.8±3.6 years	Triceps push-down machine	Fatigue without and with Cognitive stress	The three heads of triceps brachii according to SENIAM recommendations	Under all circumstances, three heads operated independently, and when tired, the non-synergist and synergist head pairs behaved similarly.
Davidson et al., 2010	Ten healthy recreationally active young men (23.5±6 1.7 years)	Non-dominant elbow isokinetic extension	Shoulder flexed at 0 or 90°	three heads of the triceps brachii and anconeus by means of intramuscular electrodes	Measures taken from a single elbow extensor muscle segment do not accurately reflect the group as a whole, and during a fatigue task, the relative activity of the two-joint

					long head varied depending on shoulder angle.
Kholinne et al., 2018	10 young, healthy, 29.2 years	Elbow extension	Five different angles of shoulder elevation; 0°, 45°, 90°, 135°, and 180°	triceps brachii long and lateral heads according to SENIAM recommendations	Every TB head has a distinct function for extending the elbow at a different elevation of the shoulder. When the elbow was stretched past 90°, all TB heads displayed increased muscular force and activation.
Naito et al., 1998	9 healthy subjects 22-34 years		From prone to supine position of the forearm while maintaining the elbow position flexed in 30, 60 and 90°	Lateral head of TB	No different activations for TB
Rendos et al., 2016	19-35 years At least 2 years of resistance training experience	Elbow extension on a selectorized cable machine.	(A), standard handle condition (B), index-middle fingers ball handle condition (C), and middle-ring fingers ball handle condition (D).	Lateral and long head of TB	Similar activity levels for the triceps
Román-Liu et al., 2018	15 healthy young adult 22.9 ±2.14	Isometric 90° Elbow extension		Lateral head TB	When acting as stabilizers during handgrip force, BB and TB differ
Serrau et al., 2012	18 active physical education students 24.1±2.2 years	Isometric 90° Elbow extension (self-resistance exercise)		Lateral head of TB	Submaximal levels of activation. Greater for TB

Therefore, further research is required to determine the degrees of muscle activation during the different exercises as well as variants for the strengthening of the triceps brachii and thus be able to make a grouping with scientific evidence and not with empirical data in which an exercise presumably affects more on one head of the TB than on another. For the purpose of choosing the TB single-joint exercises, we suggest three groups of exercises based on joint safety and effectiveness, ranging from those with the lowest mechanical load to those with the highest.

It is worth noting that during multi-joint pushing exercises, such as the bench press, although the hand is in pronation and works against gravity, the effort is not mainly focused on the elbow joints. Instead, a significant portion of the work was performed using the shoulder girdle. Therefore, the elbow joint, which has a limited range of motion (especially in lateral movements), does not bear the brunt of effort. Lehman studied the effects of pronation and supination during bench pressing. Although the electrodes were placed on the pectoralis and biceps brachii, and only on the lateral head of the TB, the electrical activity was not comparable across all three heads, even in a multi-joint elbow extension exercise (Lehman, 2005).

Less information is available on exercise safety; however, based on kinesiology, hand placement may have a greater or lesser impact on tensile forces in passive structures.

Conclusion

There is evidence to determine whether the supine or prone hand position creates extra work on one head or the other in the TB muscle. While each head can work independently through elbow and shoulder positions and lengths, the neutral hand position appears to be the most favorable for generating force (lower risk-to-benefit ratio), with maximum stability, congruence, and high coaxiality between proximal and distal joints. When working with high loads and volumes for prolonged periods, managing the stress generated in the passive structures of the elbow is crucial, particularly for certain exercises.

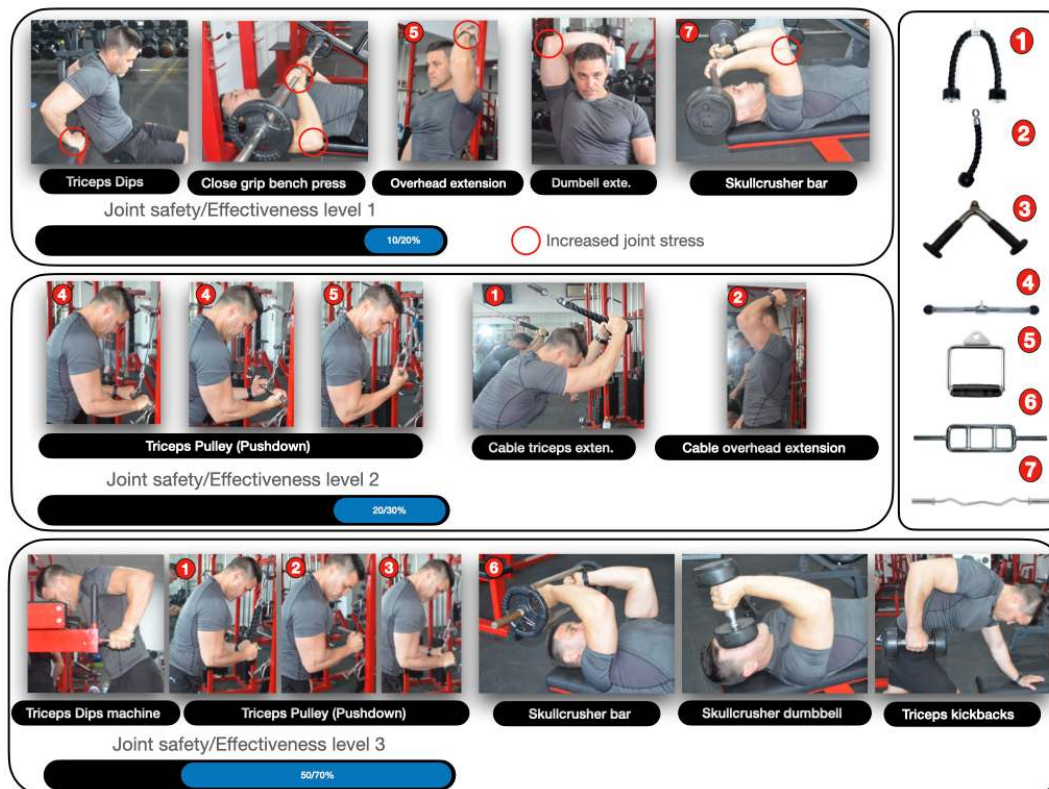
Thus, spending more time in the neutral position may be advantageous. The use of pronation or supination in some exercises may be limited to a smaller number of sets and specific contexts, such as bodybuilding or rehabilitation, while considering the exercise and context.

Practical applications

Weight RT focused on TB involves mechanical stress on the elbow and wrist joints that should be considered when designing an exercise program. In this regard, we propose three groups of exercises based on joint safety and effectiveness, starting from those with the lowest mechanical load to those with the highest, for the selection of different single-joint exercises (Figure 2).

Figure 2

Proposal in the frequent use of different exercises of TB



Note. Based on the available evidence, the authors extracted recommendations to limit the risk of injury without compromising the effectiveness of TB strengthening. These include:

- The position of the hand in supination, pronation, or semi-pronosupination does not ensure isolated work of the triceps head. However, adjusting the shoulder and elbow positions (e.g., increasing the TB length) can promote a higher level of electrical activity.
- Prioritize semi-prone supination or exercises at level 1, depending on the context (e.g., advanced athletes who require load progression, sedentary individuals, or those with elbow or wrist problems).
- The use of Level 1 exercises does not eliminate the need for Level 2 and 3 exercises. It is important to tailor the exercise program to the individual needs of each subject; in any case, “no pain, no gain” should not be a training maximum.
- Levels 2 and 3 exercises are effective and can provide variation and gains in muscular strength and hypertrophy. However, it is recommended to prioritize Level 1 exercises and gradually incorporate higher-level exercises as appropriate to minimize joint stress.

Author Contributions:

S. V. M. served as the study coordinator and designed the experiments. S. V. M., D. A. B., I. C. M. and M. G. S. collaborated in the analysis and revision of the manuscript. S.V.M., and I.C.M wrote the draft. All authors have read and approved the final manuscript.

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