International Journal of EXERCISE SCIENCE

Original Research

Comparison of Muscle Activity During a Ring Muscle Up and a Bar Muscle Up

Cody W. Walker[†1], Adam J. Bruenger[‡1], W. Steven Tucker[‡2], Hyung Rock Lee[‡1]

[1]Department of Exercise and Sport Science, University of Central Arkansas, Conway, Arkansas, United States; [2]Department of Rehabilitation Sciences, Texas Tech University Health Sciences Center, Lubbock, TX, United States

*Denotes undergraduate student author, †Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 16(1): 1451-1460, 2023. The muscle up (MU) is a variation of a common gymnastics movement that combines a pull up and a dip. It can be performed on a bar (BMU) or a set of rings (RMU). The difference in upper extremity muscle recruitment (MR) between BMU and RMU has not been evaluated. Therefore, the purpose of this study was to compare the MR of select muscles during BMU and RMU. Ten active males (27.6 ± 7.9 years) performed 5 repetitions of BMU and RMU in randomized order. Muscle recruitment of the upper (UT) and lower trapezius (LT), serratus anterior (SA), pectoralis major (PM), latissimus dorsi (LD), triceps brachii (TB), biceps brachii (BB), and forearm flexors (FF) was assessed using electromyography. A 2 X 2 ANOVA (ring vs bar, pull phase vs push phase) with repeated measures was performed for each muscle. Least significant differences post hoc tests were performed when a significant interaction effect occurred. The RMU significantly elicited more muscle activation in the UT ($p = 0.007$), BB ($p = 0.001$), and FF ($p = 0.001$) during the pull phase. The RMU also significantly elicited more muscle activation in the TB ($p = 0.025$) and BB ($p = 0.001$) during the push phase. These results suggest that the instability of the RMU primarily increases the required recruitment of the upper limbs but does not significantly change the recruitment of the shoulder stabilizers. Appropriate upper limb development is needed to perform the RMU and the BMU may be a better technique to learn first due to its lower difficulty.

KEY WORDS: Gymnastics, muscle activation, shoulder, suspension

INTRODUCTION

In recent years, body weight exercises have become increasingly popular with the general population (7). The ability to perform these exercises with little to no equipment coupled with the exercise stimulus of body weight exercises has led to this increase in use (6, 12, 16). Traditional bodyweight exercises include the pull up, dip, and push-up. The muscle up would also fall into this body weight category and could be considered a combination of the pull up and dip exercises (10).

The muscle up is a variation of a common gymnastic movement. It can be performed on either a straight bar (bar muscle up) or on rings (ring muscle up). The ring muscle up is a variation of the front up rise while the bar muscle up is a variation of the glide kip. These movements all take place in the sagittal plane and involve large upper body muscles to perform the movement (10). Much like an Olympic lift, the muscle up is a complex movement that requires both a pulling and a pushing phase. Additionally, movement is often initiated with a leg swing and drive called a kip. This motion allows the athlete to utilize momentum to help complete the movement. It is used to train the muscles of the upper shoulder girdle and arms. The pull phase of the muscle up starts from a hanging position, either from a bar or rings. The body is pulled towards the bar or rings resulting in adduction and extension of the shoulder joint and flexion of the elbow joint. As the body moves towards the bar or rings, the wrist rotates, and the athlete enters the dip phase of the movement. The dip phase starts with the athlete in shoulder extension and elbow flexion. The athlete then presses upward extending the elbow. The muscle up trains the latissimus dorsi and biceps brachii primary during the pull phase. During the dip phase, the triceps brachii and pectoralis major are primarily trained. The upper trapezius, lower trapezius, and the serratus anterior are the primary stabilizers for the scapula throughout the movement.

While there is much anecdotal discussion about the differences in bar muscle ups and ring muscle ups, no known studies have been performed to assess the differences. It is speculated that the ring muscle up will create a higher training stimulus because of the instability of the rings. Muscle recruitment has been shown to change when exercises are performed in unstable environments, compared to those same exercises being performed in a stable environment (4, 6, 9, 11, 13, 16). Specifically, De Mey et al. (7) found that, in unstable environments, muscles acting on the scapula had decreased muscle activation while muscles acting on the glenohumeral joint had increased muscle activation. This has been observed when agonist and antagonist muscles take on the role of stabilization when the body is placed in an unstable position (4, 6). For example, it has been reported that training in unstable environments increases core muscle activation and leads to an increase in functional performance measures (4, 6, 9, 16).

However, studies evaluating pulling activities in both stable and unstable conditions do not suggest there would be differences in muscle activity (8, 15). Snarr et al. (15) reported no significant difference in muscle activation of the latissimus dorsi, biceps brachii, and posterior deltoid when performing towel and a suspension pull up compared to a traditional pull up. They did report significantly lower middle trapezius activity during the towel pull up compared to a traditional pull up (15). Similarly, Dickie et al. (8) reported no difference in muscle activation of eight upper extremity muscles during a neutral grip rope pull up compared to other variations with stable hand grips. Applying the results of these studies to the muscle up is difficult. The towel and rope pull ups do not require as much movement of the upper limbs as a muscle up due to not having to transition from a pulling position to a pushing position.

Pushing studies in stable and unstable conditions have more mixed results. Lehman et al. (11) reported increased triceps activity with stability ball push-ups compared to stable push-ups but not pectoralis major or core muscle activity. However, Narin et al. (13) showed more muscle activity of the upper extremity with bench presses performed on a stability ball compared to traditional bench press and bench press with an unstable bar. The unstable bar in this study increased core stabilizer muscles to a greater extent that the other two methods of benching (13). While the pushing movement of a muscle up recruits similar muscles as a push up or bench press, the body position and movement direction of the upper limbs is different and cannot be expected to require the same muscle recruitment. These mixed results further warrant a better understanding of muscle recruitment during the bar and ring muscle up.

The benefit of understanding the differences in muscle recruitment between the bar muscle up and ring muscle up is to allow trainers to understand how to progress athletes who use the muscle up. No standardized program exists to progress an athlete to a muscle up. There is also not a standardized program that exists to help athletes progress from one muscle up variation to another and such a program cannot be developed without a better understanding of where the differences in muscle recruitment lie. Therefore, the purpose of this study was to evaluate the differences in muscle activation in the upper trapezius, lower trapezius, biceps brachii, triceps brachii, latissimus dorsi, serratus anterior, pectoralis major, and the forearm flexors during the performance of a ring muscle up and a bar muscle up. It was hypothesized that, given the inherent instability of the rings, the ring muscle up would require greater recruitment of the serratus anterior, lower trapezius, and latissimus dorsi. This hypothesis was formulated due to the role of the serratus anterior, lower trapezius, and latissimus dorsi as stabilizers of the shoulder complex during bodyweight exercises. This hypothesis was based on De Mey et al.'s (7) research on closed kinetic chain exercises performed on unstable surfaces.

METHODS

Participants

A power analysis conducted with G*Power 3.1 (Universitat, Kiel, Germany) determined 12 participants were needed for a power of 0.8, with an effect size of 0.5 and an $\alpha = 0.05$. However, only ten healthy, recreationally active male subjects (age: 27.6 ± 7.9 years; body weight: 78.0 ± 11.2 kg; training experience: 3.5 ± 2.2 years) volunteered for this study, primarily due to the requirements for inclusion. Each participant was required to engage in an active high-intensity training program that included bodyweight exercises for at least six months and be able to complete five muscle ups on the rings and using a bar. They were also required to be free of any upper extremity injuries and have no history of surgery to the upper extremity. This was assessed with a health screening questionnaire (HSQ) and by performing a NEER's test for shoulder impingement. At least 48 hours prior to the collection of data, the participants were asked to perform five sets of one muscle up on the bar to prove that they were capable of completing the tasks in the study. Prior to testing, all subjects were informed of the benefits and risk of the study and required to read, and sign approved informed consent documentation. All procedures and documents were approved by the University of Central Arkansas' Institutional Review Board prior to data collection.

Protocol
Upon arrival for testing, the participants were prepped for electrode placement. Eight muscles: the upper trapezius, lower trapezius, serratus anterior, pectoralis major, latissimus dorsi, biceps brachii, triceps brachii, and forearm flexors on the subject's dominant side were assessed for muscle activity during the muscle up exercises. The participant's dominant side was determined by asking the participants which arm they used to throw a ball. The placement of the electrode sides was based on Perotto et al.'s (14) guide for EMG placement (Table 1 and Figure 1 and 2).

Table 1. Electrode Placement following Perroto et al. (14) guidelines

Muscle	Electrode Placement
Upper Trapezius	Halfway between C7 and the Acromion
Serratus Anterior	Along the 3rd and 4th rib on the mid-axillary line
Latissimus Dorsi	Three fingerbreadths distal to and along the axillary fold
Pectoralis Major	One finger width medial of the anterior axillary fold
Lower Trapezius	Perpendicular to the spine at the level of the inferior angle of the scapular and two fingers lateral from the vertebra
Biceps Brachii	On the bulk of the muscle belly in the mid arm
Triceps Brachii	Four finger widths distal and posterior to the axillary folds
Forearm Flexors	One half the distance between the wrist and distal biceps tendon

These sites were prepped for electrode placement by shaving the skin to remove hair and cleaning the skin with an alcohol prep pad. The electrodes were spaced two centimeters from the center of the electrode. A ground electrode was placed on the clavicle.

The testing period consisted of a standardized warm up of two-minutes on a Model D concept 2 rower (Concept2 Inc., Morrisville, VT). The participant was instructed to row at a light pace on the rower while pulling 70-80 watts at 25 strokes a minute. After the warm up, the participant then performed manual muscle test (MMT) on each muscle group being evaluated. This was performed to obtain the participants' maximal voluntary isometric muscle activity for each muscle. The MMT was intended to be preformed as a maximal voluntary isometric contract (MVIC). The investigator could not, however, guarantee that no movement occurred.

The upper trapezius MMT position was with the head rotated the non-dominate side and the shoulder elevated (17). The subject was asked to resist downward force (17). The biceps brachii was tested with the participant in a seated position (17). The arm was placed on a table at 90 degrees and the forearm was placed into supination (17). The participant flexed his elbow while resistance was applied to the forearm to prevent elbow flexion (17). The forearm flexors were tested with the participant seated (17). The forearm was placed on a table and the hand cupped (17). The participant flexed his forearm while resistance was applied against the thenar eminence to prevent flexion of the wrist (17). The serratus anterior was tested with the participant seated (17). The arm was held in flexion and placed at 130 degrees of shoulder flexion (17). This was checked with a goniometer (17). Resistance was applied downward on the upper arm to prevent flexion of the shoulder (17). The pectoralis major was tested with the participant supine (17). The elbow was extended, and the shoulder flexed to 90 degrees with slight medial rotation (17). The arm was horizontally adducted towards the midline of the body (17). Resistance was applied to the forearm to prevent horizontal adduction (17). The latissimus dorsi was tested with the participant prone (17). The participant's arm was placed in an adducted, medially-rotated position and held in extension (17). Resistance was placed in the direction of abduction, against the forearm to prevent adduction of the arm (17). The lower trapezius was tested with the participant in a prone position (17). The participant's arm was abducted and laterally rotated (17). The arm was diagonal to the body (17). Resistance was applied to the forearm in a downward direction to prevent extension of the shoulder (17). The triceps brachii was tested with the participant in a prone position (17). The shoulder was placed at 90 degrees of abduction and supported by the table (17). Resistance was applied against the forearm to prevent extension of the elbow (17). Each MMT lasted five seconds and was performed three times. A minute rest was given after each test. After the participants had performed all of the MMT's, they were instructed to rest for ten minutes.

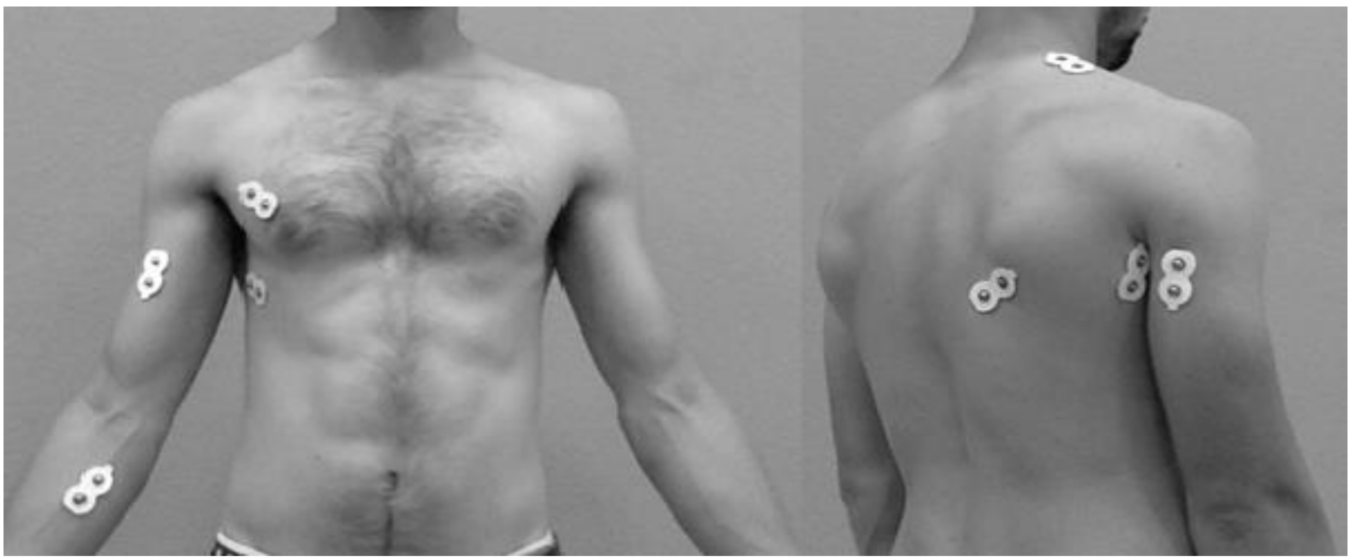

Figure 1. Electrode Placement

During this rest period, participants were asked to adjust the rings to a height that permitted them to hang from the rings, with straight legs and without their feet touching the ground. Participants were allowed to use momentum to assist in the muscle up as this is how the movement is commonly conducted. Grip width was standardized as previous studies have shown hand position to cause different muscle activation (2, 3, 18). The participant's grip width on the bar was determined by measuring the biacromial width of the shoulder. This measurement was marked with tape on the bar. At the end of the ten-minute rest period, participants preformed one set of five strict pull ups as a warm up. Participants were allowed no more than two practice muscle ups per condition prior to data collection. A minute rest was given at the end of this period and the participant then performed five sets of one muscle up on the rings or bar with a minute rest in between each set. Muscle activity was recorded using a Noraxon 8 channel telomyo 2400 G2 unit (Noraxon, Scottsdale AZ). A Microsoft webcam (Microsoft, Redmond WA) was used to collect video that was synchronized to the EMG data to determine the different phases of the muscle up. At the end of the five repetitions, participants rested five minutes and then performed five sets of one muscle up on the remaining variation of the exercise. Video was synchronized with the EMG data via the Noraxon Myomotion software (Noraxon, Scottsdale AZ).

Statistical Analysis

EMG data was analyzed via the Noraxon Myomotion software (Noraxon, Scottsdale AZ). Analysis of the muscle activity during the muscle ups was divided into two phases: a pull phase and a push phase. The start of the pull phase was defined by the legs passing into the frontal plane and ended when the participants were in the bottom part of the dip on top of the rings/bar before they started to press upward. The push phase started at the end of the pull phase and lasted until the elbows were fully extended. These phases were determined by reviewing video captured during the participant's testing that was synchronized with the EMG data. Raw EMG data were full wave rectified and the root mean squared. The middle three seconds of each MMT was analyzed for mean muscle activity and the three trials were averaged. The mean EMG data were recorded from the middle three repetitions of the muscle up movements. The processed muscle activity of each muscle up were normalized to the participant's mean MMT. A 2X2 repeated measures ANOVA was used to compare the two phases of the muscle up (push/pull), the two variations of the muscle up (bar/ring) and the effects of the two phases on the two variations. Data were analyzed using SPSS 22 (IBM, Armonk, NY). Alpha levels were set at $p \leq 0.05$. Least significant differences (LSD) post hoc tests were used when significance was found in the ANOVA.

RESULTS

Only three muscles showed significant differences in muscle recruitment between the two muscle up variations (Table 2). There was a significant interaction effect for the upper trapezius muscle activity ($F_{1,9} = 6.093$, $p = 0.036$, $\eta_p^2 = 4.04$). Post hocs revealed that the muscle activity in the pull phase of the ring muscle up was significantly greater ($p = 0.007$) than the push phase of the ring muscle up (Figure 3). There was a significant interaction effect for the triceps brachii muscle activity ($F_{1,9} = 5.426$, $p = 0.045$, $\eta_p^2 = 0.38$) (Table 2). Post hocs revealed that the pull phase of the ring muscle up was significantly less ($p = 0.045$) than the push phase of the ring muscle up. The post hoc tests also indicated that triceps brachii activation of the push phase of the ring muscle up was significantly greater ($p = 0.025$, $t = -2.69$) than the push phase of the bar. (Table 2).

There were significant main effects for phase ($F_{1,9} = 20.859$, $p = 0.001$, $\eta_p^2 = 0.70$) and for exercise variation ($F_{1,9} = 28.183$, $p < 0.001$, $\eta_p^2 = 0.76$) for the biceps brachii muscle activity (Table 2). The pull phase and ring variation produced more muscle activity than the push phase and bar variation respectively (Figure 5). Finally, there was a significant interaction effect for the forearm flexor muscle activity ($F_{1,9} = 10.486$, $p = 0.010$, $\eta_p^2 = 0.54$) (Table 2). Post hocs indicated that the muscle activity during the pull phase of the ring muscle up was significantly greater than the pull phase of the bar muscle up ($p = 0.001$). Post hocs also indicated that there was greater muscle activity during the pull phase on the rings compared to the push phase (p = 0.003) and this difference was also observed between the push and pull phases performed on the bar (p = 0.007).

Table 2. Normalized muscle activity during the push and pull phases of the bar and ring muscle up

Muscle	Normalized Muscle Activity (Mean ± SD) Pull		Push	
	Bar	Ring	Bar	Ring
Upper Trapezius	0.45 ± 0.45	**0.63 ± 0.48**	0.31 ± 0.23	**0.27 ± 0.25**
Lower Trapezius	4.32 ± 7.04	5.48 ± 8.17	4.13 ± 7.58	4.87 ± 7.56
Serratus Anterior	0.41 ± 0.33	0.64 ± 0.67	0.38 ± 0.32	0.67 ± 0.61
Triceps Brachii	1.00 ± 0.55	**1.10 ± 0.46**	**1.12 ± 0.64**	**1.7 ± 0.94**
Latissimus Dorsi	1.33 ± 1.46	1.61 ± 1.28	1.13 ± 0.98	1.23 ± 0.77
Biceps Brachii	**0.3 ± 0.17**	**0.55 ± 0.25**	**0.12 ± 0.11**	**0.39 ± 0.23**
Pectoralis Major	3.37 ± 2.78	3.75 ± 3.28	3.72 ± 4.31	3.59 ± 3.59
Forearm Flexors	**0.77 ± 0.52**	**1.05 ± 0.58**	**0.34 ± 0.19**	**0.34 ± 0.17**

* = significant ($p < 0.05$) difference between push and pull phase of the ring muscle up
** = significant ($p < 0.05$) difference between bar and ring attempts
*** = significant ($p < 0.05$) difference between push and pull phase of the bar muscle up
\# = significant ($p < 0.05$) difference between push and pull (main effect)
\#\# = significant ($p < 0.05$) difference between bar and ring (main effect)

DISCUSSION

The purpose of this study was to evaluate the differences in muscle activation in the upper trapezius, lower trapezius, biceps brachii, triceps brachii, latissimus dorsi, serratus anterior, pectoralis major, and the forearm flexors during the performance of a ring muscle up and a bar muscle up. These muscles are either primary muscles used to perform a muscle up or stabilizing muscles of the shoulder girdle. A secondary goal of this study was to determine whether the muscle activation of these movements would allow suggestions for a more standardized progression to be used when training the muscle up.

It was hypothesized that the ring muscle up would have larger muscle activation in the serratus anterior, lower trapezius, and latissimus dorsi. Our findings did not support this hypothesis. A possible reason for the observed results is both the bar and ring muscle up in this study involved a kipping motion that initiated the movement. Muscle activation in the large muscle groups may be similar because of this added variable (kip) that was not accounted for in this study. This similarity in movement may have produced similar muscle activation. The ring muscle up may require smaller muscle groups besides the ones evaluated in this study to act as stabilizers of the glenohumeral joint and thus increased activation of those smaller muscle groups. The smaller muscle groups that were evaluated in this study (triceps brachii, biceps brachii, and forearm flexors) support this hypothesis.

The results of this study showed that by adding an unstable environment (i.e., performing the muscle up on rings), muscle activation tended to increase in the upper trapezius, the biceps brachii, and the forearm flexors during the pull phase. Upper trapezius muscle activation significantly increased with the inclusion of the rings during the pull phase. The upper trapezius' role is to stabilize the scapula during upper extremity movement (18). It may be concluded that the upper trapezius is more active in an unstable environment (ring muscle up) because of a need to stabilize the scapula more during the pull phase.

The biceps brachii has been shown to have differing activation depending on grip position (19). The difference in the muscle activation of the biceps brachii could be caused by the ability of the rings to be moved around the body. When athletes performing a bar muscle up, their hands are fixed in a pronated position on the bar. However, when athletes perform a ring muscle up, their hands are in a more neutral position and allowed to rotate though multiple planes of motion during the movement.

The forearm flexor group was significantly increased in the ring muscle up during the pull phase. This could be caused by the starting hand position required to perform a muscle up. When the athlete grips the rings to perform a ring muscle up, they must use a false grip. This grip requires the hands be placed through the ring and have the rings rest on the wrist while the hand is in a flexed position. The flexed position used to achieve the false grip may have increased muscle activation of the forearm flexors when compared to the pronated grip of the bar muscle up.

Muscle activation also tended to increase in the triceps brachii and biceps brachii when the push phase was performed on the rings versus the bar. While the triceps brachii primary action is elbow extension, it has been shown to become a shoulder stabilizer when a movement becomes difficult (5, 10). Triceps brachii muscle activation has been shown to increase when the glenohumeral (GH) joint is placed in an unstable environment (7). Behm and Andersen (4) note that this increase is due to the need for more stabilization of the joint. The increase in the triceps brachii muscle activation in this study could be because of the need for the GH joint to be more stable. This increase in muscle activation could also be because the athlete might catch themselves in a deeper dip position because they do not have a bar to rest on before pressing out of the dip phase. Allen et al. (1) found increased muscle activation in the pectoralis major when using the Perfect Pushup™ system. They hypothesized that this was due to the increased range of motion required to reach the target depth in the study. Their study, however, did not find increased muscle activation in the triceps brachii using the Perfect Pushup™ system. The dip position on the rings involves the elbows being in a narrower position and closer to the body. The dip position on the bar has the elbows abducted away from the body. This change in position may have affected the activation of the triceps brachii. Biceps brachii muscle activation has also been shown to act as a shoulder stabilizer in gymnastic movements that place the GH joint in an unstable environment (5). An increase in biceps brachii muscle activation during the push phase on the ring muscle up could be from the increase in instability offered by the rings.

The small sample size was a limitation in this study. The small sample size was a result of athletes not being able to meet the inclusion criteria or by meeting an exclusion criterion. The muscle activation of the serratus anterior approached significance ($p = 0.053$) during the pull vs push phase. It can be speculated that significance might be reached with a larger sample size. Additionally, future research should focus on muscle activation in strict variations of the ring and bar muscle up to determine if kipping is the reason there was no statistical difference in muscle activity of the latissimus dorsi and pectoralis major.

Examining the muscle activation of the bar and ring muscle up may give trainers and athletes a more focused progression when training these movements. A bar muscle up requires less muscle activation in smaller muscle groups such as the forearm flexors, biceps brachii, and triceps brachii. With this in mind, a progression for athletes may focus on building the pulling strength from the larger muscle groups such as the latissimus dorsi and upper trapezius before progressing to a bar muscle up. As the athlete becomes more skilled on the bar muscle up, they may then begin practice for a ring muscle up. Exercises that build strength in the biceps and triceps would also be beneficial when training the ring muscle up. These exercises might be more effective if performed in an unstable environment. Practice should also be focused on strengthening the false grip position to help build strength in the forearm flexors.

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