

INFLUENCE OF KEY-POINTS OF RING MUSCLE-UP EXECUTION ON MOVEMENT PERFORMANCE: A DESCRIPTIVE ANALYSIS

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Abstract Background: The inclusion of gymnastic-based movements in workout routines in many exercise training programs, generally called mixed modality training (MMT), and even in many competitions, is increasingly common. In contrast to artistic gymnastic competitions, MMT workouts aim to complete as many movements as quickly as possible, which tends to deform the movement pattern proposed by artistic gymnastics. Execution of the MMT workouts with more of the gymnastics-based style (i.e., based on the gymnastics movement pattern) could improve performance in exercises with a high-level complexity, such as the “ring muscle up” (RMU). Thus, this study aimed to analyze the kinematic aspects of RMU, performed by a former gymnast both with and without the gymnastics based style.

Methods: A former gymnast with a successful transition to MMT, carried out RMU using two movement patterns: 1) close to the classical artistic gymnastics pattern (“Front uprise”), and 2) close to that used by many athletes not from gymnastics. The athlete performed RMU, three times with each proposed movement pattern. Images were captured using a high-speed digital camera. Hip and ankle displacement, velocity and acceleration were recorded and analyzed.

Results: The execution of RMU was faster and the hip vertical displacement was greater when RMU was carried out with a gymnastics-based style, while ankle displacement path, peak velocity and acceleration were lower.

Conclusion: The use of a gymnastics-based style to carry out RMU seems to be advantageous from the biomechanical point of view, favoring the performance of RMU.

Key words movement economy, artistic gymnastics, crossfit, Mixed Modality Training, kinematics

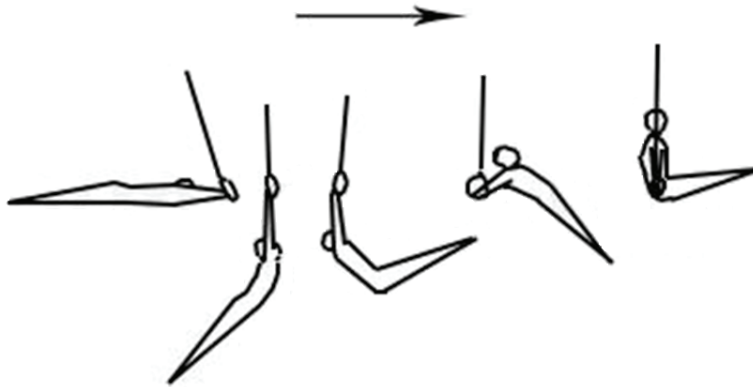
Introduction

Many trademarked exercise training programs (e.g. CrossFit, Insanity, Gym Jones, etc.) use high intensity workouts of mixed modalities, such as aerobic exercises, artistic gymnastics based movements, and weightlifting based exercises, aiming at boosting condition and strength training. As such, these exercise programs are recognized as Extreme conditioning programs (Bergeron et al., 2011), high-intensity functional training (Bechke, Kliszczewicz, Feito, Kelemen, Nickerson, 2017) and mixed modality training (MMT) (Marchini, Pereira, Pedroso, Christou, Neto, 2017; Figueiredo, Pereira, Neto, 2018).

Wide scientific knowledge exists regarding exercises such as runs, jumps, single or double under, and Weightlifting-based exercises in both physiologic and biomechanical aspects (Martin, Morgan, 1992; Comfort, Allen, Graham-Smith, 2011; DeWeese, Serrano, Scruggs, Sams, 2012), while gymnastic-based movements, despite their high-level complexity, have not been widely studied. Regularly, sport coaches have been adapting artistic gymnastics exercises, such as the “ring muscle-ups”, for us in general conditioning. In fact, there is a duality between artistic gymnastics and gymnastic based movements applied in MMT workouts, where the first is focused on the quality of movement, which includes symmetry and a perfect posture at each step of the movement, while the second is focused on intensity, carrying out as many movements as possible and/or in a little time as possible, according to the workout design (e.g. AMRAP workout: as many rounds/repetitions as possible, or “for time” workout). It is evident then that the biomechanical aspects tend to be modified/adapted from the classical artistic gymnastics when used in MMT workouts.

The increased popularity of the MMT methodology is notorious, owing to promising performance results and the motivational aspects (Claudino et al., 2018). However, some workouts requiring gymnastic skills have been associated with many movement adaptations which may result in both limited performance and the increased risk of injury (Meeusen, Borms, 1992). The exercise named “ring muscle up” (RMU) is an adaptation from the movement named “Front uprise” in artistic gymnastics, and is presented in Figure 1. Briefly, after swinging like a pendulum, the front uprise movement begin at the arch position, followed by a descending phase with the body fully extended/aligned (i.e. ankle at dorsiflexion, knee and hip extended), transiting to a forward/upward displacement with a hollow position, followed by a powerful hip extension, synchronized to a powerful pull of the rings towards the shoulders synchronized to a powerful pull of the rings at the shoulders plane (i.e. glenohumeral extension/adduction and internal rotation, with the elbow extended along the movement, combined to a scapular protraction), boosting the hip upward, while the upper body is “inverted” (i.e. displaced from a horizontal position to a vertical position, while the hip is maintained extended). The movement is finished with a hip backward displacement, until the hip reaches the plane of the rings, where the gymnast adopts the L-sit position (i.e. arms along the trunk with the body weight supported by the hands gripping the rings, hip flexion with knee extension and ankle plantar flexion).

The execution of this movement requires a high degree of motor control to keep the upper and lower body extremities “connected” to the core, i.e. the muscles need to be active along all of the movement to maintain an adequate alignment of each segment, optimizing the energy transfer between the fixed extremity (i.e. hands gripping the rings) and the free extremity (i.e. the feet). Then, from a narrow viewpoint, these mechanical aspects are essential to achieve an efficient movement, in other words, carry out the task with a minor energy demand.



Note: After swing as a pendulum, front uprise movement begin at the arch position (left/first model), followed by a descending phase with the body fully extended/aligned (i.e. ankle at dorsiflexion, knee and hip extended, as exposed in the second model), transiting to a forward/upward displacement with a hollow position (third model), followed by an powerful hip extension, synchronized to a powerful pull of the rings towards the shoulders synchronized to a powerful pull of the rings at the shoulders plan (i.e. glenohumeral extension/adduction and internal rotation, with the elbow extended along the movement, combined to a scapular protraction), boosting the hip upward, while the upper body is "inverted" (i.e. displaced from a horizontal position to a vertical position, while the hip is maintained extended, as exposed in the fourth model). The movement is finished with a hip backward displacement, up to hip reach the ring's plan, when the gymnast adopt the L-sit position (i.e. arms along the trunk with the body weight supported at hands gripped to the rings, hip flexion with knee extension and ankle plantar flexion, as exposed in the right/last model).

Figure 1. Scheme of Front uprise movement

Source: <http://www.gymdrills4profs.com/gymnastics-events/skill-drills-still-rings/gymnastics-still-rings-front-uprise.html>.

Curiously, regularly, it is possible to observe enthusiasts and athletes of MMT carrying out RMU with a different motor pattern from the "front uprise" exercise described above, which is evident in videos on social media and from events including MMT professional athletes (e.g. CrossFit Games, National Pro Grid League [NPGL-GRID] and others). A detailed analysis shows three main movement adaptations: 1) it is common to observe athletes bending the knees at the arch position, braking the body alignment at the start position, a clear sign of "connection loss" between the core and the extremities; 2) it is common to observe athletes pulling the rings to the chest, to the lower ribs, or to the hips at the "pull phase" (fourth model in Figure 1) and bending the hips and knees, which approximates the head to the knees, aiming to rotate the upper body and fit to the rings, rather than carry out an "inversion" as described for the fourth model in figure 1; 3) it is common to observe athletes needing to carry out a powerful elbow extension after the hips reach the rings plane, because they did not fit to the rings with the elbow already extended, then, they need to complete the movement, since according to the MMT movement convention and rules of competitions with the MMT design, this is a criteria to consider the movement completed (i.e. to count the repetition as valid).

All the described adaptations do not impede completion of the task, but from a kinematics point of view, it does not guarantee efficient movement, as represented by a quick movement with the least energy cost. Thus, this study aimed to analyze the kinematic aspects of RMU, performed by a former gymnast both with and without the gymnastics based style.

Materials and Methods

A Brazilian former gymnast (male; 26 years old; height: 167 cm; weight: 80 kg; 17 years of experience in artistic gymnastics, with 12 years (2001–2013) dedicated to artistic gymnastic competitions) who had a successful transition from artistic gymnastics to MMT, as confirmed by a notable performance in the main Brazilian MMT competitions, especially in workouts involving gymnastics movements such as RMU, was invited to perform RMU using two movement patterns: 1) close to classical artistic gymnastics (i.e. close to the movement pattern used in “Front uprise”); and 2) close to that used by many athletes not from gymnastics. The former gymnast exhaustively watched many videos on the adapted movement pattern as commonly used by many athletes not from gymnastics. This adapted movement pattern diverged from the classical gymnastic pattern in the three key points described previously.

All the procedures were conducted in conformity with the Helsinki Declaration and the study was approved by the local Human Research Ethics Committee (protocol #3.425.388). Written informed consent was obtained from the volunteer gymnast.

The gymnast was asked to analyze the movement patterns and reproduce them with the greatest possible precision. After analyzing the videos and practicing for a long time, six RMU performances were carried out, three times with each proposed movement pattern. Images of these movements were captured at 240 frames/sec using a high-speed GoPro® Hero 5 Black (GoPro Inc., USA) digital camera positioned 8 meters from the rings to record the movement in the sagittal plane parallel to the direction of body displacement. Selected surface anatomical reference points were marked with white tape; at the hip (greater trochanter), lateral malleolus and wrist. The tracking of hip and ankle reference points were analyzed using Kinovea® v0.8.26 software (www.kinovea.org) to produce the follow Kinematic parameters: hip and ankle displacement (total path and mean vertical displacement), velocity and acceleration during each RMU attempt. For kinematic analysis, the start position was defined as the arch position identified as the higher position before starting the downward displacement, and the end position was established as the moment when the hip reaches the ring plane and the body was aligned to the rings. These variables were obtained from each of the three attempts of each execution pattern, and the data presented as mean \pm standard deviation. The reference point attached to the wrist was used to indicate the distance between the wrist and hip when the hip reached the ring plane.

Results

Figure 2 shows the sequence of movements from an attempt of RMU in each style (i.e., Gymnastics based and MMT based).

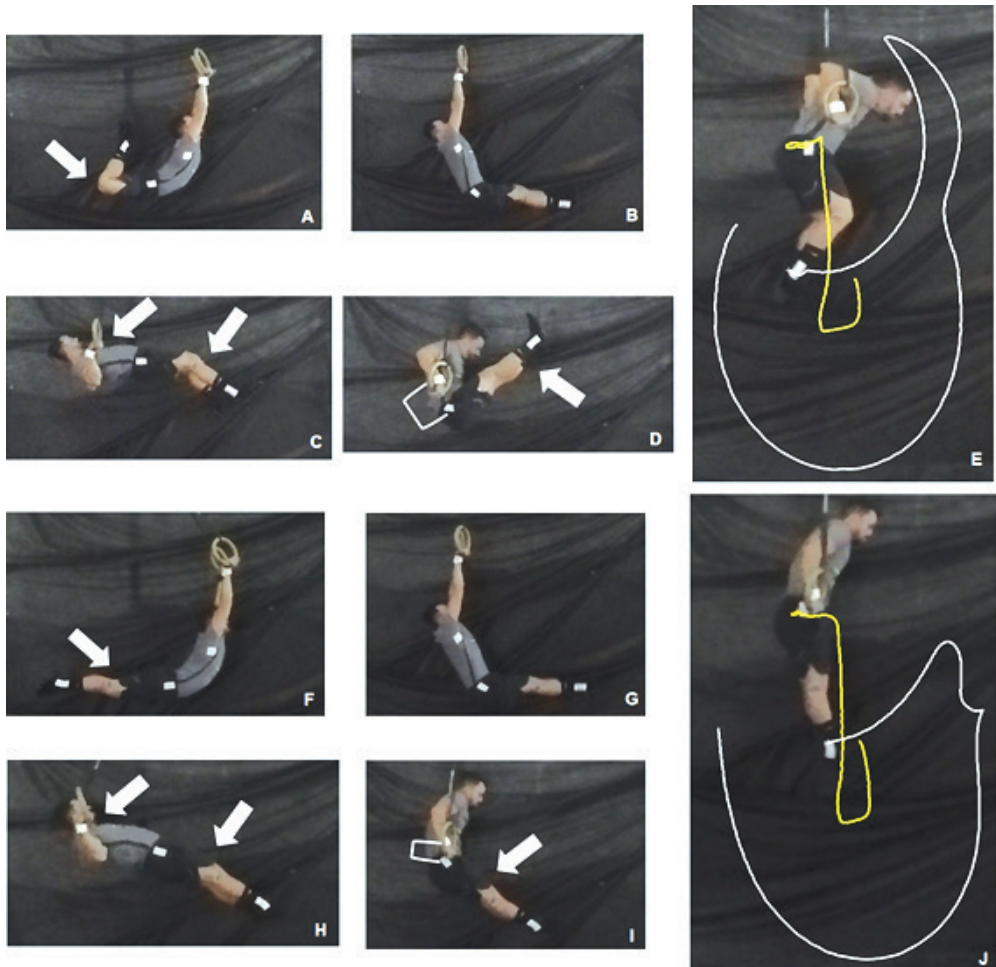
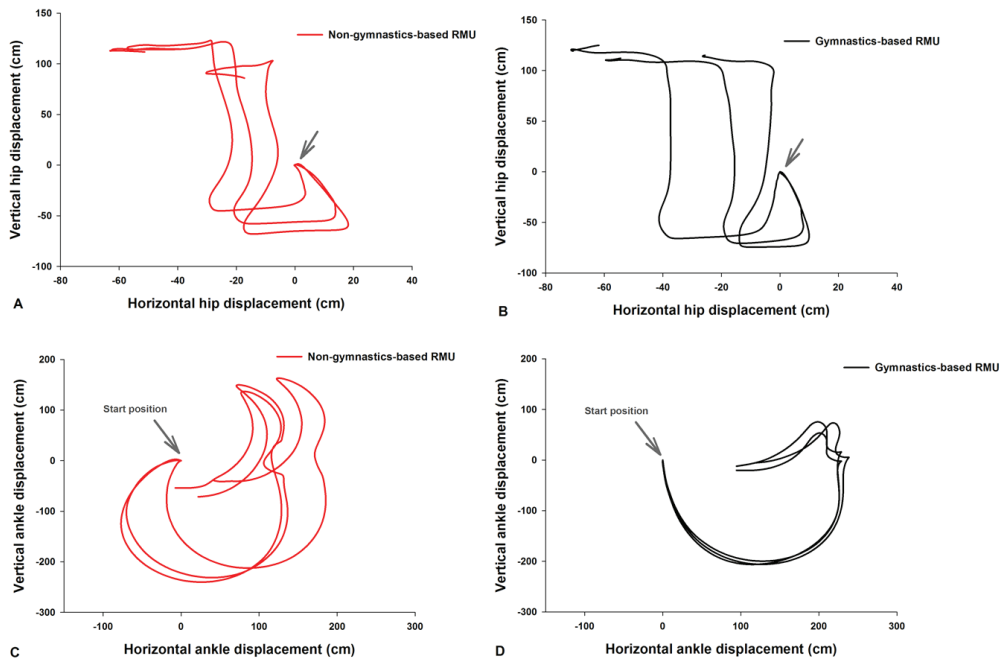


Figure 2. The sequence of movements from an attempt of RMU with each style: Non-gymnastics-based (A–E), and Gymnastics-based (F–J)

Figure 3 shows the vertical and horizontal displacements (i.e. path) of the hip and ankle during the RMU carried out with the Gymnastics style and without. It is possible to observe a distinct displacement pattern from each movement style, especially at ankle tracking.



Note: The scales were adjusted to be equal for vertical and horizontal displacement at each movement style.

Figure 3. Vertical and horizontal displacement of hip (A and B) and ankle (C and D) during three attempts of RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

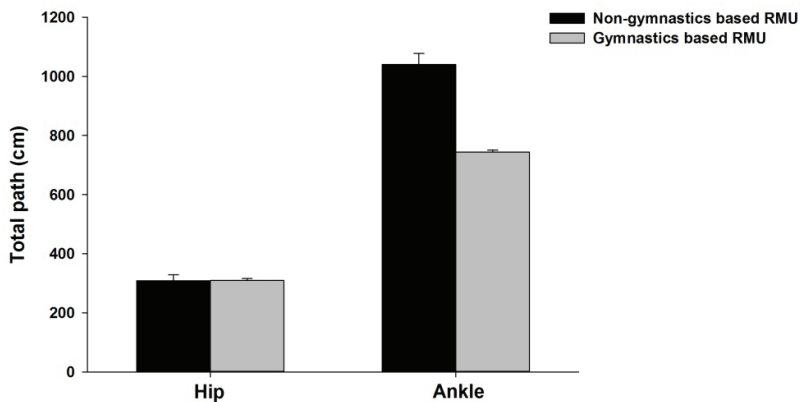


Figure 4. Mean total path of hip and ankle during the RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

Tracking of the hip and ankle during the movement exhibits a similar hip path displacement of (Non-Gymnastics-based: 308.8 ± 19.7 ; Gymnastics-based: 309.2 ± 6.9 cm), and a greater ankle path displacement without a Gymnastics-based style (Non-Gymnastics-based: 1040.1 ± 37.4 ; Gymnastics-based: 744.0 ± 6.6 cm) (see Figure 4). When analyzing the amplitude of vertical hip displacement, the gymnastics-based RMU exhibited a greater performance, since the amplitude was on average 14.7 cm greater, indicating that the hip reach a higher altitude, which facilitates the fit to the rings.

The mean time to complete the RMU was on average 268.7 milliseconds (ms) quicker when performed with a gymnastics based style, indicating that this style promotes a faster way to reach the final position, as is shown in the x-axis of Figure 5. Curiously, the peak velocity achieved with non-gymnastics-based style was on average greater for the hip (Non-Gymnastics-based: 7.1 ± 0.6 ; Gymnastics-based: 7.0 ± 1.0 m/s) and ankle (Non-Gymnastics-based: 14.1 ± 1.1 ; Gymnastics-based: 13.7 ± 0.4 m/s). The mean velocity was also greater for ankle (Non-Gymnastics-based: 6.6 ± 0.2 m/s; Gymnastics-based: 0.5 ± 0.0 m/s) with the non-gymnastics-based style, however, the hip mean velocity along the RMU was greater with gymnastics-based style (Non-Gymnastics-based: 1.9 ± 0.2 m/s; Gymnastics-based: 2.4 ± 0.1 m/s). Figure 5 exhibits the hip and ankle displacement velocity obtained during the RMU with and without the gymnastics-based style, while Figure 6 shows the respective mean and peak displacement velocities obtained.

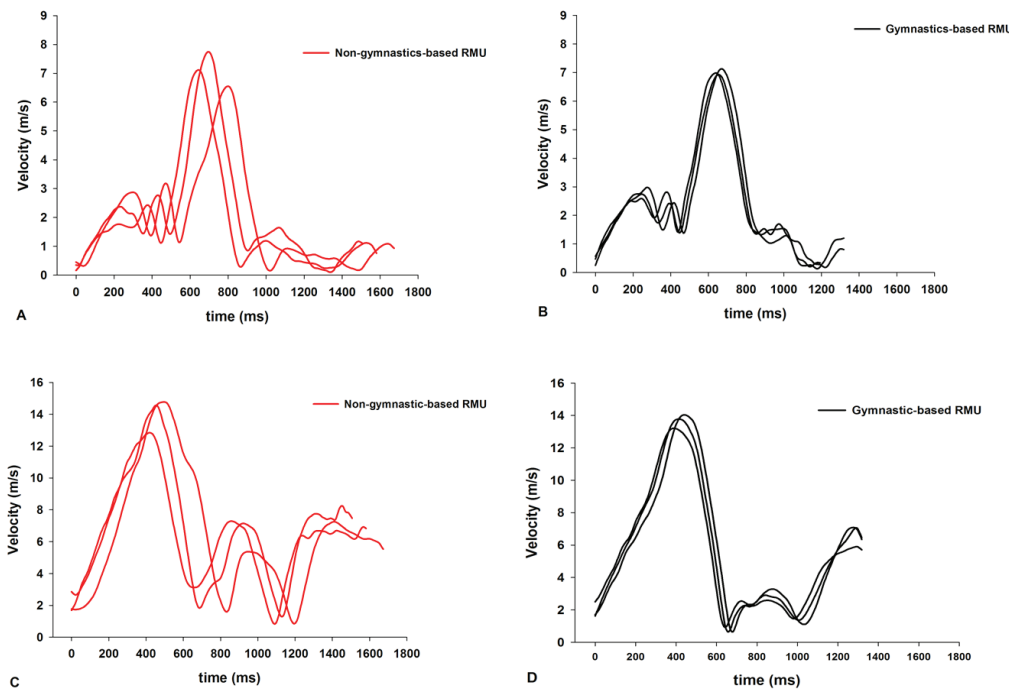


Figure 5. Hip and ankle displacement velocity during the RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

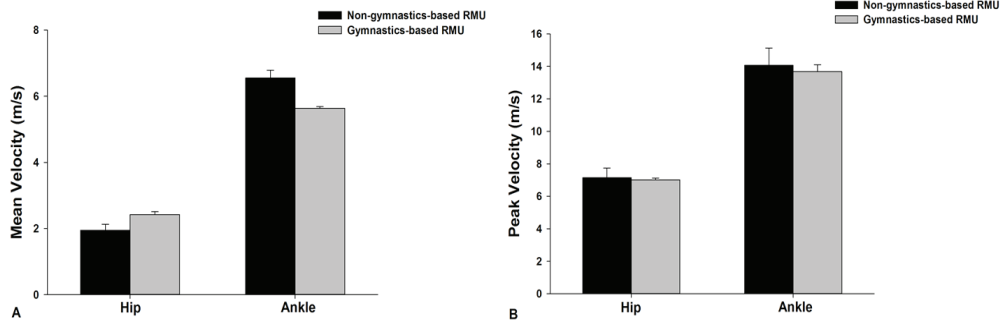


Figure 6. Mean (A) and Peak (B) velocity of hip and ankle during the RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

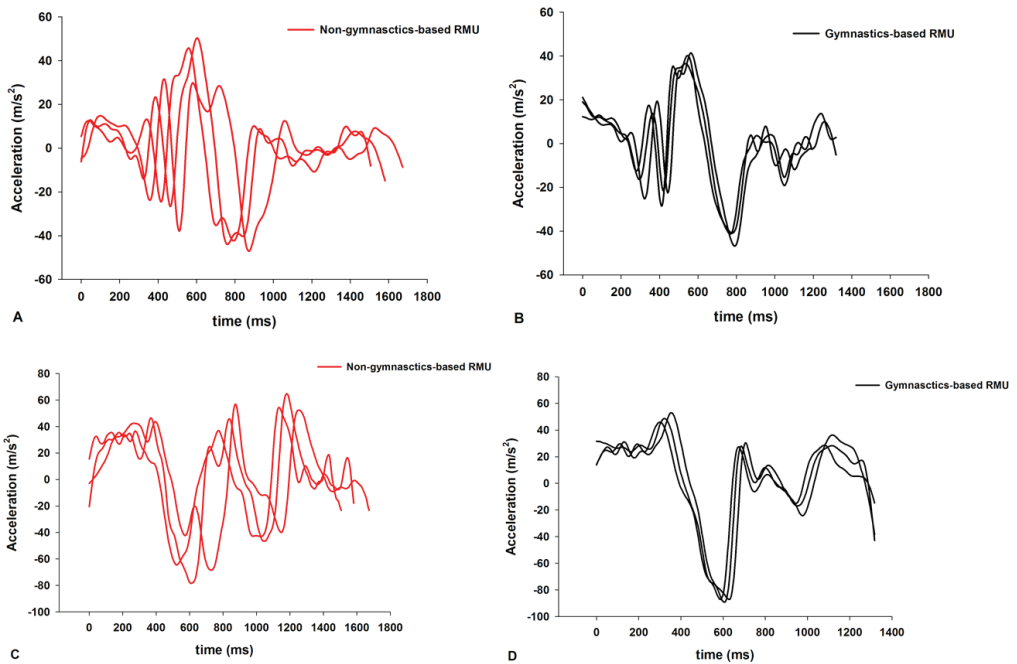


Figure 7. Hip and ankle acceleration during the RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

The peak acceleration achieved with the non-gymnastics-based style was on average greater for the hip (Non-Gymnastics-based: 42.5 ± 9.7 ; Gymnastics-based: 39.3 ± 2.6 m/s²) and ankle (Non-Gymnastics-based: 58.6 ± 5.4 ; Gymnastics-based: 49.2 ± 3.6 m/s²). The mean acceleration was also greater for the ankle (Non-Gymnastics-based: 2.7 ± 0.5 ; Gymnastics-based: 3.1 ± 0.6 m/s²) with the non-gymnastics-based style; however, the hip mean acceleration along the RMU was greater with gymnastics-based style (Non-Gymnastics-based: 0.3 ± 0.07 ; Gymnastics-based: 0.3 ± 0.3 m/s²). Figure 7 exhibits the hip and ankle displacement acceleration obtained during the RMU with and without the gymnastics-based style, while Figure 8 shows the respective mean and peak displacement acceleration obtained.

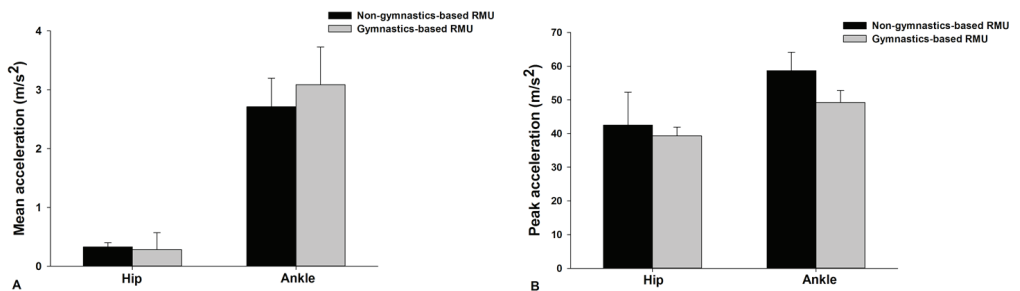


Figure 8. Mean (A) and Peak (B) acceleration of hip and ankle during the RMU carried out with (Gymnastics-based) or without a Gymnastics-based (Non-Gymnastics-based) style

Discussion

This study aimed to analyze the kinematic aspects of RMU carried out by a former gymnast in both a gymnastics-based style and the adapted MMT style. Our results showed that the gymnastics-based style allowed a faster execution with a greater vertical displacement, with a lower effort to reach this performance, as evidenced by the lower hip peak acceleration needed to reach a greater vertical displacement. In addition, the greater ankle path displacement in the non-gymnastics-based RMU evidenced an unnecessary energy demand.

It is known that biomechanical factors play a role in explaining movement economy, which have been studied in tasks such as walking and running (Martin, Morgan, 1992; IJmker, Lamoth, Houdijk, van der Woude, Beek, 2014). K.R. Williams and P.R. Cavanagh (1987) studied the relationship among running mechanics, running economy and performance, suggesting that biomechanical factors may contribute significantly in determining the economy of motion. What was subsequently hypothesized for running could be applied to other motor tasks, such as RMU. In this sense, our results indicate that the execution of RMU with an adequate body alignment between the extremities and core along the entire task, as carried out by gymnasts during many performances on the rings, could lead to a better performance with less energy expended.

For an RMU, the performance could be measured by the elapsed time to complete the task and by the height reached by the hip when crossing the ring's plane. Based on this statement, it is possible to point out that performing a RMU with a gymnastics based style (i.e. close to the movement carried out by a gymnast in "Front uprise") leads to the best performance, which is advantageous when the goal is to carry out as many repetitions as possible in a predetermined time, or a fixed number of RMUs as quickly as possible, both conditions used in many workouts proposed by trademarked exercise training programs.

In this context, the Crossfit Games®, the greatest annual competition with MMT methodology (i.e. where the applied workouts merge weightlifting and gymnastics based tasks) and whose purpose is to crown the fittest man and woman in the world, included in 2018 a task to complete 30 RMU repetitions as quickly as possible (see <https://games.crossfit.com/leaderboard/games/2018?division=1&sort=2&page1>). After observing the performance of the competitors, it is possible to identify that among men, the difference between first and second place was only 6 seconds (1st place: 1'46" [or 106 seconds]; 2nd place: 1'52" [or 112 seconds]), a very low time difference. A movement analysis of these athletes is out of the scope of the present study; however, if we reason from our results where elapsed time to complete a RMU was on average 268.7 ms faster with the gymnastics based style, it would mean that to carry out 30 RMUs, the time saved would reach 8 seconds (0.268 seconds x 30 repetitions = 8.1 seconds). Thus, it may be sufficient time to distinguish first and second place in a high level competition with MMT methodology.

It is important to note that many factors may influence the performance in the cited workout, such as cardiorespiratory capacity, muscle resistance, the number and length of rest periods, and other factors out of the scope of this study. Despite this, it seems clear that the biomechanical factors can influence RMU performance, which could favor a performance during competitive workouts.

Besides the time saved to complete the movement and the higher hip displacement reached with a gymnastics based style, it is worth emphasizing that this performance was achieved with a lower hip peak acceleration, suggesting a lower effort to complete the RMU owing to a better energy transfer along the body segments. Therefore, from the energetics point of view, it is possible to hypothesize that the gymnastics based style could be advantageous, which corroborates the hypothesis of influence of biomechanical factors on the economy of motion (Martin, Morgan, 1992; Ijmker et al., 2014). The influence of the mechanical aspects on the metabolic demands during the RMU should be considered in further studies to confirm or refute our hypothesis.

This study was based on just one athlete, which can be considered a limitation of this study, but the number of former gymnasts with a successful transition from artistic gymnastics to MMT methodology is still small, and gathering these former gymnasts, scattered in many countries, is a hard and complicated task. The present study is not a conclusive analysis, but may pave the way for further studies, gathering these athletes to improve knowledge regarding the use of gymnastics principles in the MMT. Specifically, further studies should compare the mechanical aspects and metabolic demands from non-gymnasts before and after a training period to achieve a gymnastics based RMU pattern.

In conclusion, our results suggests that the use of a gymnastics-based style to carry out a RMU, maintaining an adequate body alignment at the arch position, a hollow position at the ring's plane, associated with a powered pull toward the shoulders as used by gymnasts during "Front uprise", seem to be advantageous from the biomechanical point of view, favoring the performance of RMU, which may be especially useful during exercises with many RMU repetitions.

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Conflicts of Interest

The authors declare no conflict of interest.

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