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SportMont

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Video Analysis of Technical and Tactical Behavior in Elite Climbers

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Abstract

Climbing performance is considered multifactorial and is characterized by the interaction of technical, tactical, physical, as well as psychological components. However only few studies have investigated these components in elite climbers. The present study aimed to identify elite athletes' technical and tactical behavior regarding the following parameters: a) type of climbing handhold, b) type of climbing foothold and c) torso motion through video analysis. The sample consisted of the final competitions of IFSC Climbing World Cup Kranj (2019). In total, 543 actions were recorded through SportScout video-analysis program, taking into account the parameters a) type of climbing handhold, b) type of climbing foothold and c) torso motion. According to the results, and concerning handholds, it was observed that the majority of the participants selected to use Incuts / Mini-jugs, regardless of whether they performed the next movement with the left or the right hand. Concerning the footholds, it was found that participants mostly selected to use Big footholds regardless of whether they performed the next movement with the left or the right leg. Finally, regarding the correlation between Torso motion and Handholds and the correlation between Torso motion and Footholds, it was found that the majority of the climbers selected to perform movements without Torso twisting. Only the techniques of stepping with the right foot had a significant effect on the motion of the torso (Chi-Square=15.53, $p<0.05$).In conclusion, the selection of smaller and more difficult handholds and big footholds, as well as the climber's trunk maintenance towards the wall are highly important performance elements in elite climbers.

Keywords: *task analysis, performance, climbing*

Introduction

During the last decades, the activity of sport climbing not only has emerged as a recreational and challenging activity but at the same time has evolved into a competitive mainstream sport since the 1stWorld Championships held in Germany in the early 90s (Mittelstaedt, 1997; Sanchez et al., 2019). Nowadays, sport climbing is a fast-growing sport which was included for the first time in the 2020 Summer Olympics in Tokyo. Also, the International Olympic Committee (IOC) Executive Board officially confirmed Sport Climbing's inclusion in the program of 2024 in Paris (Sanchez et al., 2019).

Sport climbing is an intermittent activity that consists of single attempts at a climbing route of a minimum of 15 meters in length that takes from 2 to 7 minutes to be implemented, during which participants must combine their motor skills with both their cognitive and perceptual abilities (Watts, 2004; UIAA, 2006; López & Sitko, 2019; Whitaker, Pointon, Tarampi, & Rand, 2020). The climbers' aim is to reach the endpoint of a natural or artificial wall while climbing up, across or down through a pre-oriented route and returning to the base successfully (Mermier et al., 1997). The climbing attempt requires a discontinuous effort in mixed aerobic and anaerobic work (Bertuzzi et al., 2007) due to the length and inclination of the wall surface, the ascent speed, the psychological state, the physical condition, the anthropometric characteristics of the

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athlete, and the climbing methods and techniques (Mermier et al., 1997; de Geus et al., 2006; Bertuzzi et al., 2007; Matsouka et al., 2019).

According to Horst (2012), during their attempt, climbers use a plethora of climbing methods and techniques of which the most widespread are the "Three-Holds-Rule" and the "Left-Right Rule". The technique "Three-Holds-Rule" demands from the participant to climb by using three holds, in order to maintain his balance on a wall. As for the "Left-Right Rule», the participants climb the wall by using the contra lateral hand-foot in pairs (Horst, 2012). Furthermore, the sequence of movements and body positioning, in terms of grasping handholds with different features such as size and shape, the position of hands and foot, as well as torso twisting during the attempt, seem to strongly affect climbing performance (Marino & Kelly, 1988; Tucker & Ellis, 1998; Phillips, Sassaman, & Smoliga, 2012; Garrido–Vásquez & Schubö, 2014). Regarding torso twisting, when the slope of the wall surface becomes steeper, it is important for the climber to bring the body as close as possible to the wall. As the wall becomes overhanging it is much easier to reach the next handhold and move by twisting the torso sideways. Also, the torso twisting technique allows the participant to reach further (Phillips, Sassaman, & Smoliga, 2012).

The regular monitoring of the above climbing performance factors in elite climbers plays a decisive role in increasing the likelihood of success in a competition. Among various performance evaluation methods, video analysis is one of the most preferable methods for assessing the performance level of the athletes and enhancing training techniques (White & Olsen, 2010). It has been proved that movement analysis has been used extensively in team sports, such as soccer (Papadimitriou et al., 2001; Patton et al., 2020; Papadopoulos et al., 2021). However, less research has been undertaken on individual-based activities, like climbing.

What is more, to date, climbing research has mainly focused on the physiological and psychological aspects of performance (Mermier et al., 1997; Sheel et al., 2003; Aykora, 2019), while at the same time, the development and the use of observational instruments for analyzing and evaluating climbing performance elements have been limited (Taylor et al., 2020). Additionally, research to date has not identified the technical and tactical behavior of elite climbers in competition conditions and specifically regarding the parameters a) type of climbing handhold, b) type of climbing foothold and c) torso motion. Taking into consideration all the above, we strongly believe that through our findings we will enhance the knowledge of trainers and physical education teachers, so as/in order to plan specific climbing training programs for elite climbers. Moreover, we want to underline the importance of video analysis as an effective way of improving their athletes' performance, and therefore give them the chance to review their technique and make better decisions on what they have to focus on.

The present study aimed to identify elite athletes' technical and tactical behavior regarding the parameters a) type of climbing handhold, b) type of climbing foothold and c) torso motion during their climbing attempt, through video analysis, as perceived by experts.

Materials and methods

Participants

The sample of the present research was the final competitions of men and women of the IFSC Climbing World Cup Kranj 2019 / Lead finals (8 competitions for each sex of athletes). In total, 543 actions of 16 climbers (N=16) were recorded and the criterion for selecting the climbers (elite athletes) was their advancing to the final climbing round.

Moreover, for the conducting of the present study ethics approval was not required, due to the fact that no experimental analysis involving human studies was performed. Also, according to the Belmont Report (United States National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1979), the use of public images for research purposes does not require informed consent or the approval of an ethical committee.

Measurements

The SportScout (SportScout STA) video-analysis program for PC was used for the data recording regarding the following parameters: a) type of climbing handhold, b) type of climbing foothold and c) torso motion. This software is generally used to analyze both technical and tactical behavior of team and individual sports.

Procedure

Each athlete's technical and tactical behavior during his climbing attempt on the wall was examined based on Sport Climbing Assessment Tool (CM-PAT) (Taylor et al., 2020). In our study, the observation protocol was created in collaboration with a certified climbing coach by the Hellenic Ministry of Culture and Sport and contained three categories of technical-tactical actions with their respective parameters (Table 1). In total, two raters evaluated the actions and the inter-rater agreement was confirmed. In case of disagreement, consensus was reached. The observation of each ascent started from the beginning of the athlete's attempt and stopped when the athlete completed his attempt or had a fall.

Table 1. Observation protocol

1st Category - Type of climbing handhold (right hand vs. left hand)
Incuts/Mini-jugs: In general, incuts/mini-jugs consist a type of climbing handhold which is only deep enough to fit up to the second knuckle of the fingers; however, they still provide a very solid handhold.
Jugs: The term "Jugs" basically encompasses every large, easy to grab handhold. They can be held with the entire hand and sometimes with both hands.
Palming: In palming you push against the climbing wall with an open palm. This type of climbing handhold can help you to maintain balance while you reposition your feet. Also, it comes in handy if no good handholds are available and it allows you to apply counter pressure to a blank face.

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Table 1. Observation protocol

2nd Category - Type of climbing foothold (right leg vs. left leg)
Small footholds: Small footholds are small blocks that aren't big enough in order to use them for your hands but have enough surfaces to step on with the first phalanx of the big toe. In this type of foothold it is important to keep the heels low and not above the ledge level.
Big footholds: Big footholds are blocks that can bear your weight on its vertical axis and are large enough to ensure that the surface of the sole of your shoe will stay in contact with the hold. What is more, this type of foothold allows you to set yourself up for the next set of movements without extraordinary effort.
Smearing: Smearing happens when you don't have an actual foothold, so you rely on your shoe's rubber for friction against the wall surface. It is important to have as much surface contact between the sole of your shoe and the wall as possible, therefore maximizing friction.
3rd Category – Torso motion (Twisting vs. Without Twisting)
Twisting" to "Twisting": Two consecutive hand moves with simultaneous torso twisting.
"Without Twisting" to "Without Twisting": Two consecutive hand moves without torso twisting.
"Twisting" to "Without Twisting": Two consecutive hand moves. More specifically, initially, at the same time with the 1st hand move the climber performs a torso twisting motion and immediately afterwards, at the same time with the 2nd hand move he performs a motion without torso twisting.
"Without Twisting" to "Twisting": Two consecutive hand moves. More specifically, initially, at the same time with the 1st hand move the climber performs a motion without torso twisting and immediately afterwards, at the same time with the 2nd hand move he performs a torso twisting motion.

Statistics

Data were analyzed using the statistical package SPSS version 20.0 (IBM, Armonk, USA).The type of analysis used was the Crosstabs analysis and the criterion of the Chi-square test significance value p<.05. It was checked whether the frequency of occurrence of the type of climbing handhold (right hand vs. left hand) and the type of climbing foothold (right leg vs. left leg) were independent of the torso motion tactic (Twisting vs. Without Twisting).

Results

"1st Category - Type of climbing handhold (right hand vs. left hand)"

According to the results, the most frequent type of climbing handhold, both for the right (72%) and the left hand (63%),

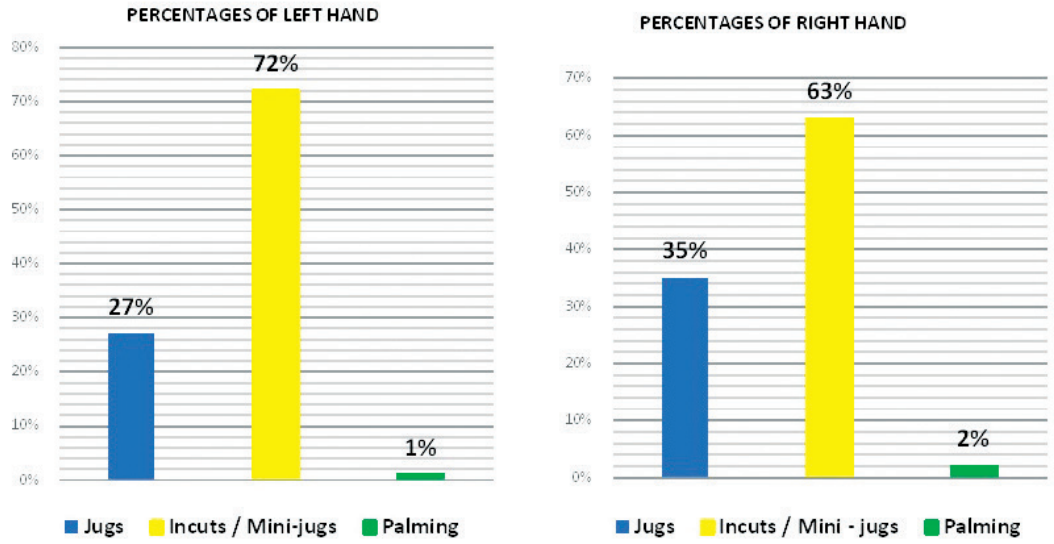

FIGURE 1. 1st Category - Handholds (Left hand vs. Right hand)

was Incuts/Mini-jugs. Jugs appeared with a smaller percentage (right hand 35%, left hand 27%) and palming with a minimum, 2% & 1% respectively (Figure 1).

"2nd Category - Type of climbing foothold (right leg vs. left leg)"

Figure 2 shows that the most frequent technique for both feet was big footholds (right 57% and left 49%). Smearing had a rate of 31% with the right leg and 37% with the left, while small footholds had a rate of 12% and 14% respectively.

"Relation between 3rd Category – Torso motion (Twisting vs. Without Twisting)"and "1st Category - Type of climbing handhold" regarding Left-hand movement

According to the results, the techniques of the left-hand grips did not significantly affect the torso motion (Chi-Square=6.33, p>.05). In particular (Figure 3), the techniques with the left hand were performed mainly without torso twisting (Incuts/Mini-jugs 70%, jugs 81%, palming 67%).

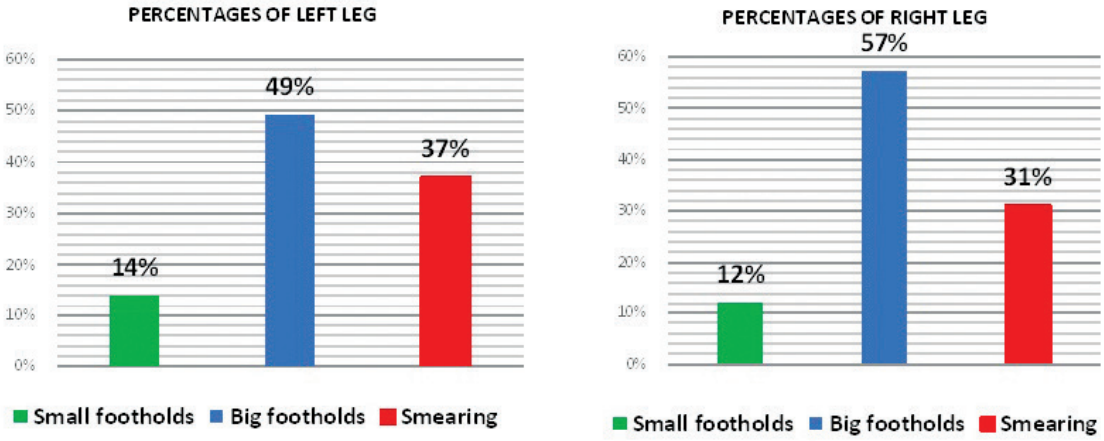

FIGURE 2. 2nd Category - Footholds (Left leg vs. Right leg)

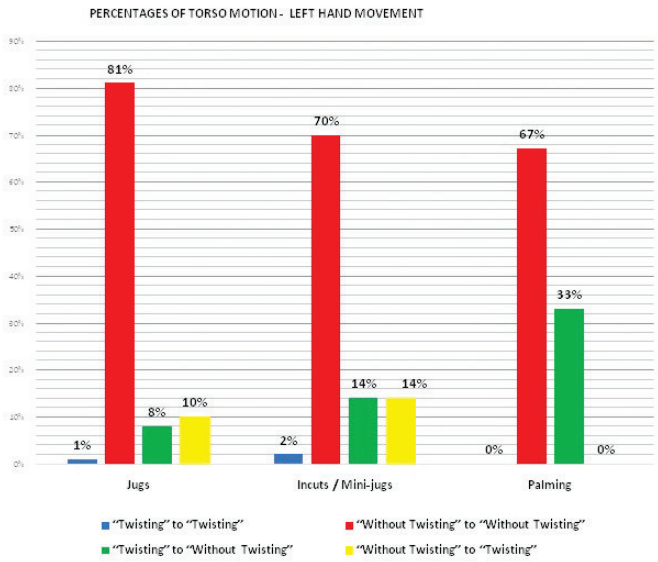

FIGURE 3. 3rd Category – Torso motion and Left hand movement

Relation between "3rd Category – Torso motion (Twisting vs. Without Twisting)" and "1st Category - Type of climbing handhold" regarding Right-hand movement

Also, the right-hand grip techniques did not significantly affect torso motion (Chi-Square=4.43, p>.05). In particular (Figure 4), the techniques with the right hand were performed mainly without torso twisting (Incuts/Mini-jugs 70%, jugs 78%, palming 83%).

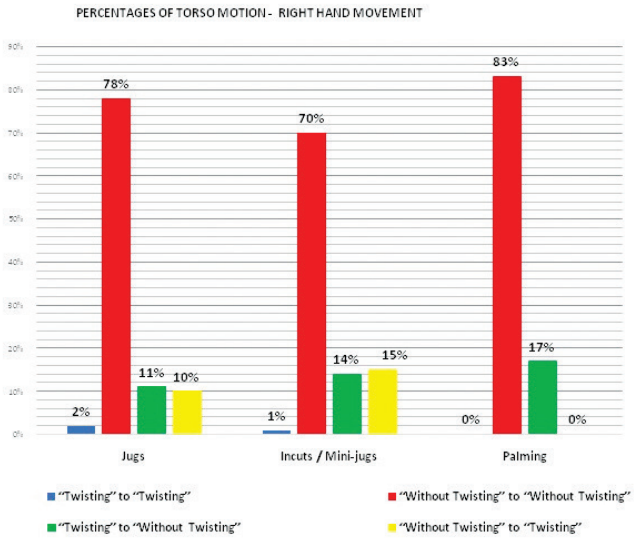

FIGURE 4. 3rd Category – Torso motion and Right hand movement

Relation between "3rd Category – Torso motion (Twisting vs. Without Twisting)" and "2nd Category - Type of climbing foothold" regarding Left leg movement

It was also found that the techniques of stepping with the left leg did not significantly affect torso motion (Chi-Square=6.43, p>.05). All techniques (Figure 5) were mainly performed without torso twisting (big footholds 72%, smearing 78%, small footholds 65%).

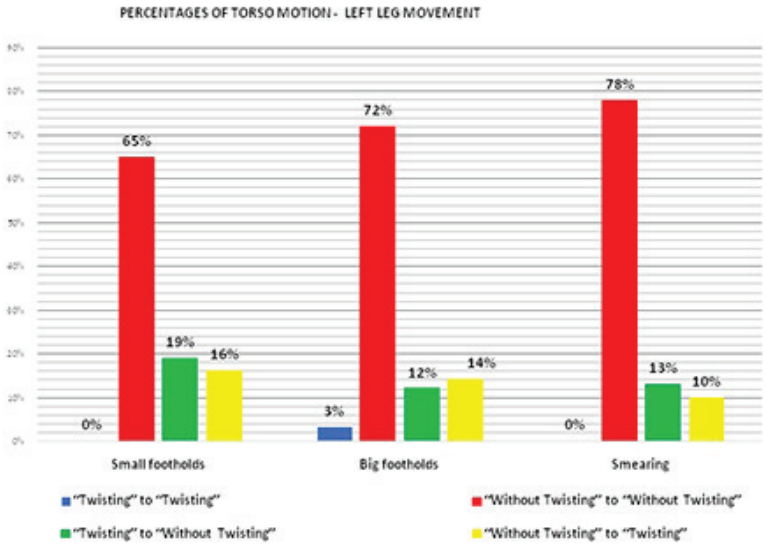

FIGURE 5. 3rd Category – Torso motion and Left leg movement

Relation between 3rd Category – Torso motion (Twisting vs. Without Twisting) and 2nd Category - Type of climbing foothold regarding Right leg movement

On the contrary, the techniques of stepping with the right foot had a statistically significant effect on torso motion (Chi-Square=15.53, p<.05). In particular, although the majority of the techniques with the right foot were mainly performed without torso twisting (big footholds 65%, smearing 80%, small footholds 91%), 19% of the big footholds were performed with "Without twisting" to "Twisting" (Figure 6).

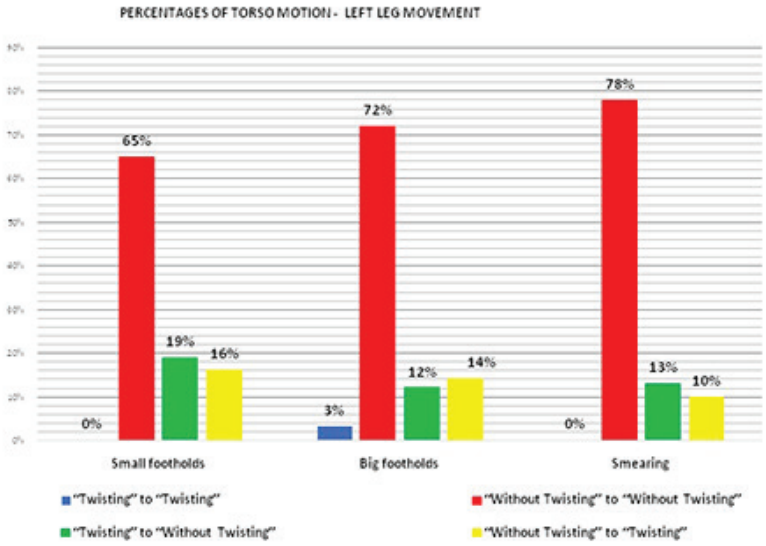

FIGURE 6. 3rd Category – Torso motion and Right leg movement

Discussion

Through video analysis, it was revealed that the selection of smaller and more difficult handholds and big footholds, as well as the climber's trunk maintenance towards the wall, are highly important performance elements in elite climbers. However, to the best of our knowledge, as this is the first study which aimed to identify elite athletes' technical and tactical behavior regarding the parameters: a) type of climbing handhold, b) type of climbing foothold and c) torso motion through video analysis, we cannot compare our results to other studies. Nevertheless, we strongly believe that our findings provide knowledge of the technical skills, as well as tactical knowledge in elite climbing athletes, which is fundamental for the understanding of individual sports performance and consequently for the adaptation of the teaching-learning training processes to competition demands.

Regarding the 1st Category - Handholds (left hand vs. right hand), it was observed that the majority of the participants selected to use "Incuts / Mini-jugs", regardless of whether they performed the next movement with the left or the right hand, as the percentages appear to be similar (72% left hand – 63% right hand). Taking into account the results of the present

study, these could be partly explained by the fact that climbers tend to grasp handholds that have ambiguous features and are usually incongruent with their responding hand, regardless of their size and shape. However, it has been proved that climbers respond significantly faster and more accurately when the functional feature is congruent with their responding hand (Tucker & Ellis, 1998).What is more, according to Garrido - Vásquez and Schubö (2014), in their attempt to implement quickly the next movement, climbers often select to grasp handholds which are closer to them, although in some cases the geometry of the object does not prove its graspness. In addition, according to Pezzulo and his colleagues (2010), elite climbers are able to hold small and difficult holds, while at the same time, they can simulate sequences of actions that are too complex, "much like how expert chess players 'see' complex strategies" (Figure 1).

Regarding the 2nd Category - Footholds (left leg vs. right leg), it was found that participants mostly selected to use "Big footholds", regardless of whether they performed the next movement with the left or the right leg (49% left leg – 57% right leg). Big footholds are blocks that can bear climbers weight on its vertical axis and are also large enough to ensure that the surface of the sole of the shoe will stay in contact with the hold. Additionally, this type of foothold allows the climber to set himself up for the next set of movements without extraordinary effort, which, according to Marino and Kelly (1988), is essential in order for the climber to conserve his upper body strength for the most difficult parts of the climb attempt. Finally, given the results of the present study, it seems that climbers selected big footholds in order to enhance their body balance and equilibrium, as it is widely known that during a large proportion of the climbing time most of the body weight is supported by the legs (Marino & Kelly, 1988) (Figure 2).

Regarding the correlation between "3rd Category – Torso motion (Twisting vs. Without Twisting)" and "1st Category - Handholds (left hand vs. right hand)", as well as the correlation between "3rd Category – Torso motion (Twisting vs. Without Twisting)" and "2nd Category - Footholds (left leg vs. right leg)", it was found that the overwhelming majority of the climbers selected to perform in all cases movements without "Torso twisting", regardless if they used a) Left or Right hand, b) Left or Right leg, c) a specific type of handhold (Jugs, Incuts/Mini jugs and Palming) or d) a specific type of foothold (Small footholds, Big footholds and Smearing). On the contrary, only the techniques of stepping with the right foot had a statistically significant effect on torso motion. In particular, although the majority of the techniques with the right foot were mainly performed without twisting the torso, 19% of the big footholds were performed with "Without twisting" to "Twisting". Similarly to our findings, Seifert and his colleagues (2015), found that the majority of the climbers during their climbing attempt spent about 55 to 75% of the time with the trunk in a face-to-wall orientation, while the rest of the time was mainly spent with the trunk in an oblique position, and less than 2% of the time was spent with the trunk side to the wall. According to Newell and McDonald (1992), these could be partially explained by the fact that the design of a climbing route has a significant impact on the climber's hip rolling motion variability and it seems that this is happening due to the meta-stability appearance in movement systems during a climbing attempt (Seifert, Boulanger, Orth, &Davids, 2015). This fact is also verified from other researchers who argued that the texture, surface, shape, size and orientation of holds invite various hand-grasping patterns and body positions (Phillips, Sassaman, & Smoliga, 2012). On the other hand, except for the effect of the design of the climbing route on trunk orientation, it has been proved that a climber's improved physical fitness factors such as postural stability and flexibility, as well as anthropometrics like height, weight and body fat, are important components for the precise movement of hands and feet, in order to gain a constant body position during the climbing attempt and achieve a better performance through the implementation of limbs' movements without torso twisting (Draper, Brent, Hodgson, & Blackwell, 2009; Stephan et al., 2011; Watts, 2004) (Figure 3 – Figure 6).

Finally, it is important to note that the small number of analyzed parameters and the insufficient testing of protocol validity and reliability constitute the limitations of the present study. Future research should focus on the evaluation of more technical and tactical parameters in elite climbers and on the development of reliable – high-profile athlete performance tools.

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Conflict of Interest
The authors have no conflict of interest to declare.

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