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Review

Performance Factors in Sport Climbing: A Systematic Review

Pelayo Diez-Fernández [1,2], Brais Ruibal-Lista [2,3,*], Javier Rico-Díaz [4], José Eugenio Rodríguez-Fernández [4] and Sergio López-García [1,2,5]

[1] Faculty of Education, Pontifical University of Salamanca, 37007 Salamanca, Spain; pdiezfe@upsa.es (P.D.-F.); slopezga@upsa.es (S.L.-G.)
[2] Research Group in Physical Activity, Sports, and Health (GIADES), Faculty of Education, Pontifical University of Salamanca, 37007 Salamanca, Spain
[3] EUM Fray Luis de León, Catholic University of Ávila, 47010 Valladolid, Spain
[4] Department of Applied Teaching, Faculty of Education Sciences, University of Santiago de Compostela, 15782 Santiago de Compostela, Spain; javier.rico.diaz@usc.es (J.R.-D.); geno.rodriguez@usc.es (J.E.R.-F.)
[5] Faculty of Education, University of Salamanca, 37008 Salamanca, Spain
* Correspondence: brais.ruibal@frayluis.com

Abstract: Background: Our aim was understanding and identifying the main performance factors involved in sport climbing. Methods: A systematic review was conducted using the Google Scholar, Dialnet, Scielo, and Redalyc databases. Results: After establishing the selection criteria, a total of 27 documents related to the subject of study were examined. A limited number of publications with scientific evidence related to performance factors in sport climbing were found, despite the rise of sport climbing following its inclusion in the Olympic Games in Tokyo 2020. The results have been organized based on different performance factors analyzed, such as strength, muscular endurance, psychological factors, etc. Key determinants in climbing performance, and thus those present in elite athletes, include improved climbing efficiency, greater ability to apply maximum force or finger and palm pressure resistance, and increased arm locking strength. Additionally, it has been observed that those who can apply higher and more consistent loads experience better muscle oxygenation and have greater flexibility and lateral foot reach. Conclusions: Climbing performance is the result of factors that can be enhanced through training. Therefore, further research is needed to understand the performance factors involved in this sports discipline and how to improve them.

Keywords: climbing; performance; strength; psychology; technique

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1. Introduction

The fundamental principle of sustainability implies that choices and actions in the present should not jeopardize the ability to preserve or enhance the quality of life in the future [1]. It is a complex system consisting of four dimensions: social, economic, environmental, and political/institutional, characterized by the interactions within each of these dimensions [2].

Engaging with nature through activities like ecotourism and outdoor recreation raises awareness about the importance of conserving natural resources and protecting historical and cultural sites. This fosters a positive attitude towards the environment and its preservation [3].

There is a growing concern about the impacts of sports activities on the natural environment, emphasizing the urgent need for proper management to minimize negative consequences and move towards a more sustainable approach [4,5].

Participating in activities in natural settings leads to an appreciation of these places and motivates people to maintain physical fitness to engage in such activities, whether sporadic or for health benefits [6].

Furthermore, as Caballero [7] suggests, physical activities in natural environments are conducive to instilling positive values in young individuals, including responsibility, autonomy, empathy, cooperation, healthy lifestyle habits, and leadership.

Hence, our goal is to study the performance factors influencing sport climbing, which directly relate to nature-based sports like rock climbing, a sport gaining popularity worldwide and reflected in there being climbing walls everywhere.

2. Literature Review

Climbing is a sport that involves phases of movement between moments of rest, and its success relies on the climber's ability to move fluidly between these resting points [8]. It is an increasingly popular recreational and competitive sport. For its preparation and training, it is important to understand the anthropometric and physiological factors, study the body's responses to training, and apply precise stimuli, as these insights will enable the specific training focus for climbing disciplines: difficulty, bouldering, and speed. Climbing is physiologically unique in the need for sustained and intermittent isometric muscle contractions for upward propulsion [9].

Attempting to make an initial approach toward understanding the performance factors in sport climbing, the authors [10] established a model composed of six parameters or factors: coordination and technique, tactical aspects, psychological aspects, physical aspects, environmental conditions, and external conditions for the climber.

Recent research has focused on various areas within the field of sport climbing. Some of the investigated topics include anthropometry [11,12], muscle fatigue [13–16], energy expenditure [10–13], the relationship between heart rate and maximal oxygen consumption [17–20], intermittent isometric endurance [12,21], reoxygenation of finger and hand flexor muscles [22,23], technical–tactical aspects of climbing [17,24–26], and psychophysiological aspects related to climbing, such as problem-solving skills, movement sequence memory, climbers' anxiety levels, or specific stress management training, which can be critical discriminators of performance in sport climbing [19,27–30].

Furthermore, an athlete's skill and precision can be determinants of performance and can be defined as opportunities for action in a sports performance environment with reference to the individual [31]. Before applying force to a hold, climbers may make small adjustments based on how they perceive the hold and their capabilities. This exploratory behavior can be important for improving the amount of friction that can be exerted on the hold [26].

In the same vein, in the pursuit of greater efficiency in climbing and prolonging the time until fatigue sets in, climbers aim to transfer maximum weight onto their feet. This results in energy savings in the upper body, especially in the forearms, which are the primary culprits of fatigue while climbing [16,21].

Climbing is a sport with high demands for strength, but numerous authors have also emphasized the importance of the relationship between this factor and technical–tactical factors. It has been suggested that climbers with higher technical–tactical levels have better optimization of climbing rhythm [32], better positioning of their center of gravity, and a grip strength application that generates more friction on holds [26]. This allows them to shorten contact phases with holds, saving energy expenditure and isometric work [17], which promotes higher performance. Additionally, flexibility has been identified as one of the key physical abilities, along with strength, that determines success in climbing [8,11,19,23,26–33].

With this review work, following the PRISMA methodology, the goal is to achieve an understanding and identification of the primary performance factors involved in sport climbing.

3. Materials and Methods

A systematic review of the current scientific literature on sport climbing was conducted following the guidelines of "Preferred Reporting Items for Systematic Reviews and Meta-

Analyses" (PRISMA) [34]. Such reviews are highly valuable as they allow for the synthesis of scientific information on a specific topic [35].

3.1. Search Strategies

To carry out this systematic review, the following search strategies were employed. Initially, a search for articles related to the subject matter was conducted using the following databases: Google Scholar, Dialnet, Scielo, and Redalyc.

For the search, the terms or keywords used and the search pattern employed by combining the terms in different search engines were as follows: (sport climbing) AND [(performance factors) OR (strength) OR (psychology) OR (endurance) OR (technique)].

3.2. Eligibility Criteria

The eligibility criteria for including and excluding data in this systematic review were as follows:

3.2.1. Inclusion Criteria

1. Observation of variables related to any type of information regarding determining factors for performance in sport climbing.
2. Any type of study that analyzes the effects of a training program with the aim of determining which factors a sportsperson should develop to enhance their performance in sport climbing.
3. Variables have been assessed with specific tests for sport climbing.
4. Participants were adults with a minimum experience of at least two years.
5. Documents published in the 20 years prior (spanning from 1996 to 2016, inclusive) to the official confirmation of Tokyo as the Olympic host city (Tokyo 2020) in 2016.

3.2.2. Exclusion Criteria

1. Studies involving minors or adults with no prior experience in sport climbing.
2. Inconclusive studies.
3. Studies in which variables corresponded to non-specific tests in sport climbing.
4. Documents published prior to 1996 and after 2016.

3.3. Data Collection Procedure

Following the inclusion criteria explained previously, an initial individual review was carried out by two reviewers, ensuring greater consistency during the process of document analysis and screening [36].

In this initial review, articles that did not relate to the topic based on their titles and abstract content were discarded. Subsequently, a more thorough reading of the literature was conducted to decide upon the inclusion or exclusion of articles. Finally, a total of 27 articles were selected.

Figure 1 illustrates the four phases outlined by the PRISMA Statement: identification, screening, eligibility, and inclusion of documents [37].

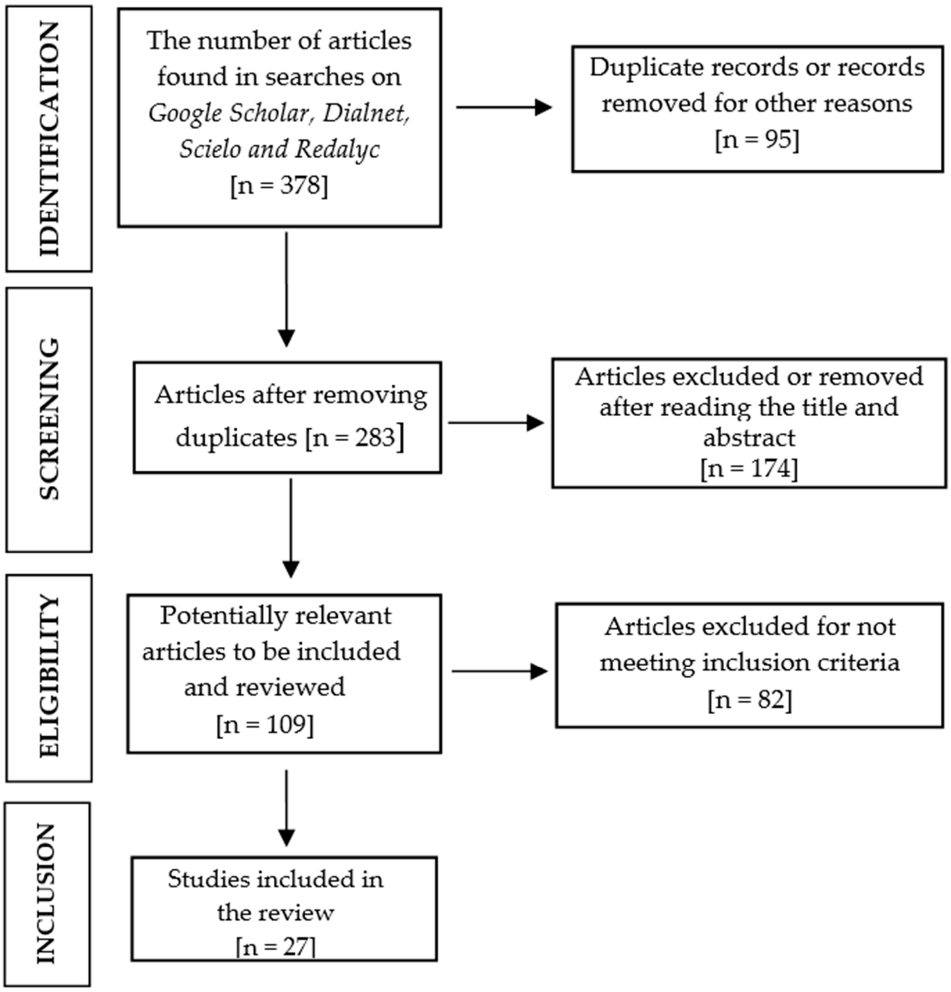

Figure 1. PRISMA flowchart.

4. Results

In Table 1, the results of this systematic review under the applied criteria are displayed. The following table presents the analysis of the 26 documents.

Table 1. Analysis of performance factors in interventions with sport climbers.

Reference	Participants	Protocol	Results
Bertuzzi et al., 2007 [17]	6 elite climbers and 7 recreational climbers	Comparison of the energy systems used by both groups while climbing.	Both groups utilized the same energy systems. Elite climbers demonstrated better climbing economy and, as a result, performed better on steeper walls.
Baláš et al., 2014 [38]	26 advanced and elite male climbers	Measurement of physiological variables during a specific treadmill climbing test. Climbing wall height: 3 m. Inclination: 90–105°.	The increase in heart rate (HR) and maximal oxygen consumption (VO2max) were related to the inclination of the wall.
Cuadrado et al., 2007 [39]	30 intermediate climbers	Comparison of two strength and endurance training programs	Strength and endurance training leads to improvements in specific climbing factors. Endurance training serves as a means to achieve a certain level of specific strength.

Table 1. *Cont.*

Reference	Participants	Protocol	Results
Draper et al., 2009 [8]	10 medium climbers, 9 advanced, and 2 elite	Flexibility test, lateral foot reach, and foot stepping.	There is a relationship between flexibility and climbing ability. Flexibility can be a significant determinant of performance in climbers.
Draper et al., 2011 [40]	29 competitive climbers (17 men, 12 women)	Psychological evaluation: fatigue, anxiety, stress, confidence.	Greater experience influences self-confidence, reduces stress, and increases the likelihood of success.
Deyhle et al., 2015 [41]	11 male climbers	Impact of prior fatigue in different muscle groups on performance.	Finger and elbow flexors were more critical muscle groups for climbing performance.
Donath et al., 2013 [42]	28 climbers (14 recreational, 14 advanced)	Determination of differences in load application based on climbing level.	Higher-level climbers demonstrated higher and more consistent load applications.
Fryer et al., 2016 [43]	36 males and 10 females (advanced climbers)	Maximum isometric finger flexor suspensions.	Higher climbing levels were associated with a higher index of oxidative capacity in the deep finger flexor. The oxidative capacity index is a good predictor of climbing performance.
Fryer et al., 2013 [44]	21 climbers (18 males, 3 females)	Comparison of stress levels between lead and second climbing.	Higher-level climbers were not significantly affected by stress during lead climbing.
Grant et al., 1996 [45]	10 elite climbers and 10 recreational climbers	Comparison of key performance indicators in climbing.	Elite climbers exhibited better finger strength, scapular waist strength, and hip flexibility.
Grant et al., 2001 [46]	30 women (10 elite, 10 recreational, 10 non-climbers)	Comparison of performance factors: grip strength.	Elite women demonstrated greater finger strength compared to recreational and non-climbing women.
Gáspari et al., 2015 [47]	8 elite climbers	Lactate test in competition: post-warm-up, post-semifinals, post-finals.	Lactate peak occurred after finals, indicating increased anaerobic involvement in higher technical difficulty climbs. Higher lactate levels were observed in competitions compared to training.
Hardy y Hutchinson, 2007 [28]	10 experienced climbers	Evaluation of anxiety levels in climbers of different levels.	Higher anxiety levels were positively correlated with performance and increased climbing difficulty.
Heyman et al., 2009 [48]	13 male amateur climbers with over 3 years of experience	Active recovery, passive recovery, electrostimulation, and cold-water immersion.	Active recovery and cold-water immersion can enhance a climber's ability to return to an optimal working state.
López y Badillo, 2012 [49]	9 elite males and 1 elite female	Isometric suspensions: 18 mm with maximum load in 5, and 11 mm for maximum time.	The most effective method is to initially train on a larger hold with additional weight and then on a smaller hold without weight.
Magiera et al., 2013 [21]	30 intermediate-level males	Analysis of somatic characteristics, specific physical fitness, technical and tactical skills, and on-sight climbing performance.	Maximum finger strength, mental endurance, climbing technique, isometric finger endurance, decision making, arm length, and VO2UAN correspond to 77% of performance capacity.

Table 1. *Cont.*

Reference	Participants	Protocol	Results
MacLoed et al., 2007 [22]	20 subjects (11 intermediate climbers, 9 non-climbers)	Comparison of specific finger endurance.	Muscle reoxygenation was higher in climbers and positively correlated with climbing performance.
Mermier et al., 1997 [50]	14 experienced climbers (9 males, 5 females)	Measurement of physiological variables while climbing three routes with different inclinations.	A nonlinear relationship between the increase in VO2max and heart rate (HR) during climbing was observed.
Mermier et al., 2000 [11]	44 climbers (24 males, 20 females)	Comparison of anthropometric measurements, flexibility, muscle strength, muscular endurance, and explosive strength.	Nearly 2/3 of the variation in climbing performance could be explained by trainable factors. Anthropometric factors had a small impact on climbing performance.
Nieuwenhuys et al., 2008 [51]	12 novice climbers (7 males, 5 females)	Evaluation of the effects of anxiety on visual information processing during climbing.	Anxiety led to poorer information processing during climbing in novice climbers.
Rodio et al., 2008 [20]	13 climbers (8 males, 5 females)	Measurement of lactate, energy expenditure, and VO2 consumption during climbing.	Energy expenditure and VO2 during climbing were similar to values obtained during easy and moderate aerobic activities.
Sánchez et al., 2012 [52]	29 male climbers	Evaluation of the effects of pre-route visualization on performance at different climbing levels.	Only expert climbers benefited from pre-route visualization.
Schöffl et al., 2006 [15]	28 male climbers	Analysis of performance measures taken while ascending on a treadmill.	Moderate lactate accumulation was observed, and reduced HR was considered useful as an indicator of recovery.
Vigoreaux et al., 2015 [53]	25 subjects (12 climbers—9 males and 3 females—and 13 non-climbers)	Comparison of finger flexor capabilities.	Both male and female climbers exhibited stronger finger flexors compared to non-climbers.
Wall et al., 2004 [54]	18 women (6 intermediate, 6 advanced, 6 elite)	Assessment in 2 different climbing tests and strength evaluations.	Elite female climbers showed better finger strength and one-arm lock-off strength than advanced and intermediate climbers.
Watts et al., 1996 [16]	11 elite climbers	Measurement of finger strength in manual pressure and blood lactate evolution after several intervals of maximum-intensity climbing.	Both grip strength and endurance decreased after several climbing intervals. Grip strength recovered faster than endurance, and blood lactate remained elevated after a 20 min full test.

HR: heart rate; VO2: oxygen consumption; VO2max: maximum oxygen consumption; VO2UAN: oxygen consumption at anaerobic threshold.

Out of the 26 articles considered, 4 were published before the year 2000. In comparison, 11 were published between 2000 and 2010. Lastly, the remaining 11 were published more recently, after the year 2010.

The samples used and analyzed in the various studies have been quite diverse. They have mixed different types of participants, ranging from non-climbers or amateurs to elite climbers.

Regarding the participants' levels, elite or advanced climbers were present in nine documents [16,28,38–40,43,47,49,50]. Similarly, four studies included climbers of a defined intermediate or beginner level [21,39,42,51], and only two studies used a sample of athletes of a beginner or recreational level [48,53]. Lastly, eight documents combined different levels, from amateur climbers to elite climbers [8,17,22,42,45,46,53,54]. The level of participants was not described in the rest of the studies.

On the other hand, regarding the gender of the athletes, nine studies included individuals of both sexes [11,20,40,43,44,49–51,53]. Similarly, two studies worked exclusively with women [27,44], and six studies focused on male subjects [15,21,38,41,48,55]. The gender of the sample used was not detailed in the rest of the studies.

In a different context, analyzing the various protocols applied or the objectives pursued in the different studies reviewed, it was found that concerning physiological variables, some authors have focused their efforts on analyzing them at a general level [38,50]. Others have chosen specific performance-related physiological factors such as lactate [16,20,47]. Likewise, some have focused on finding the best recovery mechanisms [48] or the main energy systems involved in climbing motor patterns [17].

On the other hand, some researchers have worked with different performance factors or measures related to Basic Physical Capacities (BPCs) applied to climbing [11,15,46]. Similarly, some authors have investigated finger flexion strength, endurance or arm locking strength [23,53,54], or handgrip strength [46], or compared the influence of different strength and/or endurance training programs [39]. Lastly, flexibility has also been studied through lateral foot reach tests [8], load distribution [42], or force applied in isometric suspensions [43,49].

Similarly, attempts have been made to analyze psychological parameters that influence climbing performance. The main parameters studied have been anxiety [28,40,51], stress [40,44], psychological fatigue [40], or the influence of route visualization prior to climbing [56].

In this same line, this review has found that the determining performance factors in climbing, and therefore those present in elite athletes, are better climbing economy [17], those who apply more maximum finger or palmar pressure strength, as well as greater arm locking strength [21,39,41,45,46,53,54], those who apply higher and more consistent loads [42], those with better muscular oxygenation [22,43], and those with better flexibility or lateral foot reach [8]. Therefore, climbing performance is a result of multiple trainable factors [11].

Finally, experience allows for better control of psychological factors such as anxiety, stress, or fatigue [28,40,41,44,51]. It also leads to better outcomes following route visualization [52].

5. Discussion

This systematic review aimed to identify the performance factors influencing rock climbing. In relation to the objective of this work, it is worth noting the limited number of publications found related to this field. For this systematic review, 26 documents related to performance factors influencing sport climbing were used.

Sport climbing, whether indoors or outdoors, is an increasingly popular recreational and competitive activity practiced worldwide. The inclusion of sport climbing in the 2020 Tokyo Olympics, with three sub-disciplines, lead climbing, speed climbing, and bouldering, provides an opportunity for the sport to continue growing [56]. Consequently, research related to this sport has increased, as athletes can benefit from advancements in the scientific understanding of performance determinants in sport climbing [11]. Sport climbing involves specific movements and techniques [55] and is associated with various performance factors due to the unique nature of the sport.

This review has identified crucial factors that determine performance in climbing, which have also been observed in elite climbers. These factors include optimal climbing economy, as seen in a previous study [17], as well as the ability to generate maximum finger and palm strength, along with arm locking strength, supported by previous research [16,21,22,39,41,45,53,54]. Handgrip strength, as analyzed in [46], is also a significant factor. Additionally, the authors of [57] explain that hand–arm strength and endurance, along with body fat percentage and climbing experience, can predict climbing performance satisfactorily.

Similarly, it has been observed that climbers categorized as elite athletes are capable of applying higher and more consistent loads during their ascent, as evidenced in [42]. Additionally, it has been highlighted that these athletes have better muscular oxygenation [22,43] and greater flexibility and lateral range of motion in the lower body segments, as confirmed in [8]. As demonstrated in [58], climbers with more experience are able to spend less time and force on holds and increase the coefficient of friction on necessary footholds.

Regarding anthropometry or body composition, the dimensions of body segments in relation to climbing performance have been studied [12], although some authors suggest that anthropometry has a small impact on climbing performance [11]. Some studies have also emphasized the importance of hip [8,46] and shoulder mobility [11,54].

The technical–tactical aspects of climbing, such as decision making, strategies used by climbers during their ascent, and the ability to visually inspect a route before climbing it, can represent essential components of performance optimization. With shorter stops, only expert climbers benefited more from previewing the route [52]. Furthermore, the climber's ability to adapt their focus or perception of the hold before applying force or movement seems to be another important factor in the ascent [31]. This exploratory behavior has been identified as an essential element for optimizing the friction that can be generated on holds [26].

On the other hand, there are other aspects that can influence performance enhancement in sport climbing tests. Energy drinks have demonstrated their effectiveness in physical tests across various sports such as cycling, athletics, triathlon, or rowing [59].

This was also evidenced in sport climbing, where nine non-professional climbers underwent three different tests: a maximum speed pull-up, a series of pull-ups to exhaustion, and a climbing test that was repeated on two occasions [60].

The results demonstrated that with caffeine intake, there was a 19% increase in power in the maximum speed pull-up test, a 13.5% increase in the maximum number of pull-ups to exhaustion, and a decrease in the time invested in the climbing test, by 13.8% in the first attempt and 18.6% in the second [60].

Other studies that have conducted systematic reviews of the literature conclude that the profile of a climber should include a low percentage of body fat, low overall weight, elevated levels of strength, particularly in manual grip, resistance to repeated muscle contractions, high aerobic capacity, and good shoulder and hip flexibility [61].

Lastly, psychophysiological aspects related to climbing have been explored, including problem-solving ability, memory for movement sequences, anxiety levels, and stress management training, whereby all of which can significantly influence performance in sport climbing [19,27–30]. The results of another study indicated that basic processes of perception, memorization, and information processing, along with motivational and emotional aspects, decisively influence climbing practice [62].

Taken together, these findings support the notion that climbing performance is a result of a variety of factors that can be improved through training [11,58].

In the United Nations (UN), in the year 2015, the world's top leaders presented the 2030 agenda with a set of 17 objectives known as the Sustainable Development Goals (SDGs). These objectives aim to enhance the lives of all individuals [63].

These 17 objectives have replaced the Millennium Development Goals (MDGs) and are organized into six core elements, such as ensuring a healthy quality of life and caring for the environment and ecosystems, among others [64].

SDG 3 aims to improve the health and well-being of all individuals. Therefore, through the promotion and practice of physical activities, specifically rock climbing or sports, we will be contributing to achieving this Sustainable Development Goal. Since physical activity in any of its forms is a highly significant component in contemporary society, it promotes an understanding of the value of movement in people's health and well-being.

Maintaining an active and healthy lifestyle has the potential to prevent future health issues in children and offers benefits for both physical health and psychological aspects [65,66]. Furthermore, Sustainable Development Goal (SDG) number 15 aims to achieve the care, sustainability, and preservation of terrestrial ecosystems by protecting and promoting the sustainable use of the terrestrial natural environment [63].

Therefore, terrestrial ecosystems are essential for human survival, contributing to over half of the global GDP and playing a role in various heritage, cultural, spiritual, and economic values [62]. In this context, the physical practice of climbing goes beyond the pursuit of thrills and physical challenges. Apart from providing vigorous exercise and a rewarding experience in nature, climbing establishes a deep connection with the environment.

Climbers often find themselves immersed in spectacular natural environments, fostering a deeper appreciation of the beauty and fragility of nature. This connection can lead to a greater respect for the environment and heightened awareness of the importance of conservation. Climbers frequently become passionate advocates for the preservation of natural areas and the adoption of sustainable practices. Simultaneously, climbing promotes responsibility and care for natural surroundings, as climbers rely on the integrity of rocks and natural structures for their enjoyment and safety.

In summary, climbing not only provides physical and emotional benefits but also nurtures a special bond with the environment, motivating those who practice it to protect and conserve the natural environments that they deeply enjoy.

6. Conclusions

Sport climbing is a sport that combines isometric contraction phases and movement phases in the vertical plane, ascending from the ground to different heights, using various holds, the wall, and upper and lower body segments for support.

The main performance factors that influence this sport, which can be trained to achieve the best competition results, are related to greater intermittent isometric resistance to muscle fatigue and greater muscle strength and pressure exerted primarily by the muscles of the hand and fingers. Additionally, aerobic metabolism plays a primary role, but the involvement of anaerobic metabolism and lactate production increases with the wall's inclination.

On the other hand, technical–tactical aspects of climbing, the climber's experience, and the control of psychophysiological factors such as anxiety, stress, or the ability to visualize the route before the ascent also play a significant role. Similarly, anthropometric factors such as joint flexibility in the involved movements and the length of body segments (arms and legs) have a notable impact on performance and the climber's ascent.

7. Limitations and Future Directions

This study poses two limitations. First, the search did not include studies that may be included in databases such as Scopus or Web of Science, which could have provided more results.

Secondly, all of the searches were carried out before 2016. Because climbing was included as an Olympic sport in that year, the number of investigations has been able to increase since then.

However, it is important to emphasize that this work aims to be the first part of a comprehensive analysis of performance factors related to climbing. Its inclusion in the 2016 Rio Olympic Games has marked a significant milestone in the history of this sport, elevating its profile globally and generating an unprecedented interest in its analysis and understanding.

Therefore, the second part of this research will focus on analyzing the quantity and quality of scientific evidence regarding sport climbing from 2016 to the present, in order to compare the results with those of the current study.

The rigorous analysis of all of this information can contribute to identifying areas for improvement in terms of regulations, safety, and dissemination, thus promoting the assurance of safe and ethical practices at all levels of competition, as well as enhancing performance among professional athletes.

Consequently, the careful examination of evidence related to sport climbing following its Olympic debut becomes an essential component for understanding its scope and potential impact on the world of contemporary sports.

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References

1. Repetto, R. *The Global Possible-Resources, Development and the New Century*; Yale University Press: New Haven, CT, USA, 1985.
2. Inglés, E.; Puig, N. Sports management in coastal protected areas. A case study on collaborative network governance towards sustainable development. *Ocean Coast. Manag.* **2015**, *118*, 178–188. [CrossRef]
3. Salazar, C. *Recreación*; Editorial Universidad de Costa Rica: San José, Costa Rica, 2007.
4. Dingle, G. Sustaining the race: A review of literature pertaining to the environmental sustainability of motorsport. *Int. J. Sports Mark. Spons.* **2009**, *11*, 80–96.
5. Mallen, C.; Stevens, J.; Adams, L.; McRoberts, S. The Assessment of the Environmental Performance of an International Multi-Sport Event. *Eur. Sport Manag. Q.* **2010**, *10*, 97–122. [CrossRef]
6. Jiménez Oviedo, Y.; Núñez, M.; Vega, E.C. La actividad física para el adulto mayor en el medio natural. *InterSedes Rev. Sedes Reg.* **2013**, *16*, 168–181. [CrossRef]
7. Caballero, P. El desarrollo positivo y las actividades físicas en el medio natural. *Tándem Didáctica Educ. Física* **2014**, *45*, 42–52.
8. Draper, N.; Brent, S.; Hodgson, C.; Blackwell, G. Flexibility assessment and the role of flexibility as a determinant of performance in rock climbing. *Int. J. Perform. Anal. Sport* **2009**, *9*, 67–89. [CrossRef]
9. Salomon, J.C.; Vigier, C. *Pratique de L'escalade*; Ed. Vigot: Tokyo, Japan, 1989.
10. Goddard, D.; Neumann, U. *Performance Rock Climbing*; Stackpole Books: Mechanicsburg, PA, USA, 1993.
11. Mermier, C.M.; Janot, J.M.; Parker, D.L.; Swan, J.G. Physiological and anthropometric determinants of sport climbing performance. *Br. J. Sports Med.* **2000**, *34*, 359–366. [CrossRef]
12. Watts, P.; Joubert, L.M.; Lish, A.K.; Mast, J.D.; Wilkins, B. Anthropometry of young competitive sport rock climbers. *Br. J. Sports Med.* **2003**, *37*, 420–424. [CrossRef]
13. Grant, S.; Shields, C.; Fitzpatrick, V.; Mingloh, W.; Whitaker, A.; Watt, I.; Kay, J.W. Climbing-specific finger endurance: A comparative study of intermediate rock climbers, rowers and aerobically trained individuals. *J. Sport Sci.* **2003**, *21*, 621–630. [CrossRef]
14. Schöffl, V.; Klee, S.; Strecker, W. Evaluation of physiological standard pressures of the forearm flexor muscles during sport specific ergometry in sport climbers. *Br. J. Sports Med.* **2004**, *38*, 422–425. [CrossRef]
15. Schöffl, V.; Mockel, F.; Kostermeyer, G.; Roloff, I.; Kupper, T. Development of a performance diagnosis of the anaerobic strength endurance of the forearm flexor muscles in sport climbing. *Int. J. Sports Med.* **2006**, *27*, 205–211. [CrossRef]
16. Watts, P.; Newbury, V.; Sulentic, J. Acute changes in handgrip strength, endurance, and blood lactate with sustained sport rock climbing. *J. Sports Med. Phys. Fit.* **1996**, *36*, 255–260.
17. Bertuzzi, R.C.; Franchini, E.; Kokubun, E.; Kiss, M.A. Energy system contributions in indoor rock climbing. *Eur. J. Appl. Physiol.* **2007**, *101*, 293–300. [CrossRef] [PubMed]
18. de Geus, B.; Villanueva O'Driscoll, S.; Meeusen, R. Influence of climbing style on physiological responses during indoor rock climbing on routes with the same difficulty. *Eur. J. Appl. Physiol.* **2006**, *98*, 489–496. [CrossRef] [PubMed]
19. Sheel, A.W. Physiology of sport rock climbing. *Br. J. Sports Med.* **2004**, *38*, 355–359. [CrossRef]
20. Rodio, A.; Fattorini, L.; Rosponi, A.; Quattrini, F.M.; Marchetti, M. Physiological adaptation in noncompetitive rock climbers: Good for aerobic fitness? *J. Strength Cond. Res.* **2008**, *22*, 359–364. [CrossRef] [PubMed]
21. Magiera, A.; Roczniok, R.; Maszczyk, A.; Czuba, M.; Kantyka, J.; Kurek, P. The structure of performance of a sport rock climber. *J. Hum. Kinet.* **2013**, *36*, 107–117. [CrossRef] [PubMed]

22. MacLeod, D.; Sutherland, D.L.; Buntin, L.; Whitaker, A.; Aitchison, T.; Watt, I.; Bradley, J.; Grant, S. Physiological determinants of climbing-specific finger endurance and sport rock climbing performance. *J. Sports Sci.* **2007**, *25*, 1433–1443. [CrossRef] [PubMed]
23. Philippe, M.; Wegst, D.; Müller, T.; Raschner, C.; Burtscher, M. Climbing-specific finger flexor performance and forearm muscle. oxygenation in elite male and female sport climbers. *Eur. J. Appl. Physiol.* **2011**, *112*, 2839–2847. [CrossRef]
24. Arbulu, A.; Lapresa, D.; Usabiaga, O.; Castellano, J. Detección y aplicación de T-Patterns en la escalada de élite. *Cuad. Psicol. Deporte* **2016**, *16*, 95–102.
25. Arbulu, A.; Usabiaga, O.; Castellano, J. Construcción de una herramienta de observación de escalada de élite y la estimación de la calidad del dato. *Rev. Iberoam. Psicol. Ejerc. Deporte* **2016**, *11*, 91–96.
26. Fuss, F.K.; Weizman, Y.; Burr, L.; Niegl, G. Assessment of grip difficulty of a smart climbing hold with increasing slope and decreasing depth. *Sports Technol.* **2013**, *6*, 122–129. [CrossRef]
27. Draper, N.; Jones, G.; Fryer, S.; Hodgson, C.; Blackwell, G. Effect of an on-sight lead on the physiological and psychological responses to rock climbing. *J. Sports Sci. Med.* **2008**, *7*, 492. [PubMed]
28. Hardy, L.; Hutchinson, A. Effects of performance anxiety on effort and performance in rock climbing: A test of processing efficiency theory. *J. Sports Sci.* **2007**, *20*, 147–161. [CrossRef] [PubMed]
29. Llewellyn, D.J.; Sanchez, X. Individual differences and risk taking in rock climbing. *Psychol. Sport Exerc.* **2008**, *9*, 413–429. [CrossRef]
30. Watts, P. Physiology of difficult rock climbing. *Eur. J. Appl. Physiol.* **2004**, *91*, 361–372. [CrossRef] [PubMed]
31. Seifert, L.; Orth, D.; Button, C.; Brymer, E.; Davids, K. An Ecological Dynamics Framework for the Acquisition of Perceptual–Motor Skills in Climbing. In *Extreme Sports Medicine*; Feletti, F., Ed.; Springer: Cham, Switzerland, 2017.
32. Bourdin, M.; Pastene, J.; Germain, M.; Lacour, R. Influence of training, sex, age and body mass on the energy cost of running. *Eur. J. Appl. Physiol. Occup. Physiol.* **1996**, *66*, 439–444. [CrossRef]
33. Giles, L.V.; Rhodes, E.C.; Taunton, J.E. The physiology of rock climbing. *Sports Med.* **2006**, *36*, 529–545. [CrossRef]
34. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; Prisma Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. *PLoS Med.* **2009**, *6*, e1000097. [CrossRef]
35. Sánchez-Meca, J. Cómo realizar una revisión sistemática y un meta-análisis. *Aula Abierta* **2010**, *38*, 53–64.
36. González, I.F.; Urrútia, G.; Alonso-Coello, P. Revisiones sistemáticas y meta análisis: Bases conceptuales e interpretación. *Rev. Española Cardiol.* **2011**, *64*, 688–696. [CrossRef] [PubMed]
37. Beltrán, O.A. Revisiones sistemáticas de la literatura. *Rev. Colomb. Gastroenterol.* **2005**, *20*, 60–69.
38. Baláš, J.; Panáčková, M.; Strejcová, B.; Martin, A.J.; Cochrane, D.J.; Kaláb, M.; Kodejška, J.; Draper, N. The relationship between climbing ability and physiological responses to rock climbing. *Sci. World J.* **2014**, 1–6. [CrossRef]
39. Cuadrado, G.; De Benito, A.M.; Flor, G.; Izquierdo, J.M.; Sedano, S.; Redondo, J.C. Estudio de la eficacia de dos programas de entrenamiento de la fuerza en el rendimiento de la escalada deportiva. *Motricidad. Eur. J. Hum. Mov.* **2007**, *19*, 61–76.
40. Draper, N.; Dickson, T.; Blackwell, G.; Fryer, S.; Priestley, S.; Winter, D.; Ellis, G. Self-reported ability assessment in rock climbing. *J. Sports Sci.* **2011**, *29*, 851–858. [CrossRef] [PubMed]
41. Deyhle, M.R.; Hsu, H.S.; Fairfield, T.J.; Cadez-Schmidt, T.L.; Gurney, B.A.; Mermier, C.M. Relative Importance of Four Muscle Groups for Indoor Rock Climbing Performance. *J. Strength Cond. Res.* **2015**, *29*, 2006–2014. [CrossRef]
42. Donath, L.; Roesner, K.; Schoffl, V.; Gabriel, H.H.W. Work-relief ratios and imbalances of load application in sportclimbing: Another link to overuse-induced injuries? *Scand. J. Med. Sci. Sports* **2013**, *23*, 406–414. [CrossRef]
43. Fryer, S.; Stoner, L.; Stone, K.; Giles, D.; Sveen, J.; Garrido, I.; Espana-Romero, V. Forearm muscle oxidative capacity index predicts sport rock-climbing performance. *Eur. J. Appl. Physiol.* **2016**, *116*, 1479–1484. [CrossRef]
44. Fryer, S.; Dickson, T.; Draper, N.; Blackwell, G.; Hillier, S. A psychophysiological comparison of on-sight lead and toprope ascents in advanced rock climbers. *Scand. J. Med. Sci. Sports* **2013**, *23*, 645–650. [CrossRef]
45. Grant, S.; Hynes, V.; Whittaker, A.; Aitchison, T. Anthropometric, strength, endurance and flexibility characteristics of elite and recreational climbers. *J. Sports Sci.* **1996**, *14*, 301–309. [CrossRef]
46. Grant, S.; Hasler, T.; Davies, C.; Aitchison, T.C.; Wilson, J.; Whittaker, A. A comparison of the anthropometric, strength, endurance and flexibility characteristics of female elite and recreational climbers and non-climbers. *J. Sports Sci.* **2001**, *19*, 499–505. [CrossRef]
47. Gáspari, A.; Berton, R.; Lixandrão, M.; Perlotti-Piunti, R.; Chacon-Mikahil, M.; Bertuzzi, R. The blood lactate concentration responses in a real indoor sport climbing competition. *Sci. Sports* **2015**, *30*, 228–231. [CrossRef]
48. Heyman, E.; De Geus, B.; Mertens, I.; Meeusen, R. Effects of Four Recovery Methods on Repeated Maximal Rock-Climbing Performance. *Med. Sci. Sports Exerc.* **2009**, *41*, 1303–1310. [CrossRef]
49. López-Rivera, E.; González-Badillo, J. The effects of two maximum grip strength training methods using the same effort duration and different edge depth on grip endurance in elite climbers. *Sports Technol.* **2012**, *5*, 100–110. [CrossRef]
50. Mermier, C.M.; Robergs, R.A.; McMinn, S.M.; Heyward, V.H. Energy expenditure and physiological responses duringn indoor rock climbing. *Br. J. Sports Med.* **1997**, *31*, 224–228. [CrossRef] [PubMed]
51. Nieuwenhuys, A.; Pijpers, J.R.; Oudejans, R.R.D.; Bakker, F.C. The influence of anxiety on visual attention in climbing. *J. Sport Exerc. Psychol.* **2008**, *30*, 171–185. [CrossRef]
52. Sánchez, X.; Lambert, P.; Jones, G.; Llewellyn, D.J. Efficacy of pre-ascent climbing route visual inspection in indoor sport climbing. *Scand. J. Med. Sci. Sports* **2012**, *22*, 67–72. [CrossRef] [PubMed]

53. Vigouroux, L.; Goislard de Monsabert, B.; Berton, E. Estimation of hand and wrist muscle capacities in rock climbers. *Eur. J. Appl. Physiol.* **2015**, *115*, 947–957. [CrossRef] [PubMed]
54. Wall, C.B.; Starek, J.E.; Fleck, S.J.; Byrnes, W.C. Prediction of indoor climbing performance in women rock climbers. *J. Strength Cond. Res.* **2004**, *18*, 77–83.
55. Woollings, K.Y.; McKay, C.D.; Emery, C.A. Risk factors for injury in sport climbing and bouldering: A systematic review of the literature. *Br. J. Sports Med.* **2015**, *49*, 1094–1099. [CrossRef]
56. Lutter, C.; El-Sheikh, Y.; Schöffl, I.; Schöffl, V. Sport climbing: Medical considerations for this new Olympic discipline. *Br. J. Sports Med.* **2017**, *51*, 2–3. [CrossRef] [PubMed]
57. Baláš, J.; Pecha, O.; Martin, A.J.; Cochrane, D. Hand–arm strength and endurance as predictors of climbing performance. *Eur. J. Sport Sci.* **2012**, *12*, 16–25. [CrossRef]
58. Fuss, K.F.; Niegl, G. Instrumented climbing holds and performance analysis in sport climbing. *Sports Technol.* **2008**, *1*, 301–313. [CrossRef]
59. Burke, L.M. Caffeine and sports performance. *Appl. Physiol. Nutr. Metab.* **2008**, *33*, 1319–1334. [CrossRef] [PubMed]
60. Cabañes, A.; Salinero, J.J.; Del Coso, J. La ingestión de una bebida energética con cafeína mejora la fuerza-resistencia y el rendimiento en escalada deportiva. *Arch. Med. Deporte* **2013**, *30*, 215–220.
61. España-Romero, V.; Artero, E.G.; Ortega, F.B.; Jiménez-Pavón, D.; Gutiérrez, A.; Castillo, M.J.; Ruiz, J.R. Aspectos fisiológicos de la escalada deportiva. *Rev. Int. Med. Cienc. Act. Física Deporte* **2009**, *9*, 264–298.
62. Sánchez, X.; Torregrossa, M. El papel de los factores psicológicos en la escalada deportiva: Un análisis cualitativo. *Rev. Psicol. Deporte* **2005**, *2*, 177–194.
63. Organización de las Naciones Unidas (ONU). *Informe de los Objetivos de Desarrollo Sostenible (ODS)*; Edición Especial. Editorial ONU, 2023. Available online: https://www.un.org/sustainabledevelopment/es/ (accessed on 9 October 2023).
64. Uzcátegui, O. Objetivos de desarrollo sostenible 2015–2030. *Rev. Obstet. Ginecol. Venez.* **2016**, *76*, 73–75.
65. Ortega, F.B.; Ruiz, J.R.; Castillo, M. Actividad Física, condición física y sobre peso en niños y adolescentes: Evidencia procedente de estudios epidemiológicos. *Endocrinol. Nutr.* **2013**, *60*, 458–469. [CrossRef]
66. Yanci, J.; Vinuesa, A.; Rodriguez, J.; Yanci, L. El tiempo de compromiso motor en las sesiones de Educación Física del primer y segundo ciclo de Educación Primaria. *Sport. Sci. J.* **2016**, *2*, 239–253. [CrossRef]