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Validity and Reliability of Finger Strength Assessment Methods in Climbing: A Systematic Review

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ADMINISTRATIVE INFORMATION

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INTRODUCTION

Review question / Objective This systematic review aims to evaluate the validity and reliability of various finger strength assessment methods used in climbers, with a focus on different testing protocols and devices (e.g., dynamometers, force sensors) and their impact on performance outcomes in climbing.
PICO Breakdown
Population (P): Climbers of different levels, from amateur to elite, of both genders, aged between 10 and 60 years.
Intervention (I): Finger strength assessment using various methods, including dynamometers, force platforms, and grips in different positions (half crimp, open hand, etc.).
Comparator (C): Comparison between different devices (dynamometers, force sensors) and grip positions (depths and hand positions).
Outcomes (O): Reliability (measured by Intraclass Correlation Coefficient, ICC) and validity of tests in relation to climbing performance.

Rationale The increasing popularity of rock climbing, particularly following its inclusion in the Tokyo 2020 Olympic Games, has led to a surge in both recreational and competitive participation at various levels, including youth, university, and international circuits. With this growth, the demand for effective performance and injury prevention strategies has also escalated, especially given the prevalence of injuries among elite climbers. One critical determinant of climbing performance is finger strength, particularly the isometric strength of finger flexors, which has been shown to correlate strongly with climbing ability.

Despite numerous studies addressing finger strength in climbers, there remains a lack of standardization in the assessment methods. Variations in the testing protocols, grip positions, and the equipment used to measure finger strength complicate the comparison of results across studies. Additionally, there is limited evidence regarding the reliability and validity of these methods, particularly when used across different levels of climbing expertise. Given that

accurate and consistent finger strength measurements are crucial for evaluating climbers' performance and guiding training interventions, there is a clear need for a systematic review that consolidates the current evidence on the validity and reliability of finger strength assessments.

This systematic review aims to fill this gap by evaluating the reliability and validity of different finger strength assessment methods used in climbing, identifying which methods are most effective, and determining the factors that influence the precision and applicability of these tests. In doing so, this review will provide a comprehensive overview of the current state of knowledge and highlight areas for future research, thereby contributing to the development of standardized assessment protocols that can improve both performance outcomes and injury prevention in climbers.

Condition being studied The condition being studied in this review focuses on the assessment and training of finger strength in rock climbers. Finger strength, particularly in the flexor muscles, is a key determinant of climbing performance, as it directly influences a climber's ability to grip and hold onto surfaces during ascents. Various grip types, such as crimp, half crimp, and open hand, require different levels of isometric strength and endurance, making the accurate evaluation of finger strength essential for developing effective training programs.

In climbing, the ability to generate and sustain high levels of force with the fingers is crucial for success, especially in advanced and elite athletes. The assessment of finger strength provides valuable insights into a climber's physical capabilities and helps guide targeted training interventions. By using reliable and valid methods to evaluate finger strength, coaches and athletes can monitor progress, optimize training loads, and enhance overall performance. This review aims to examine the different methodologies used for finger strength assessment in climbers, contributing to the development of standardized protocols that can improve training outcomes and performance across all levels of the sport.

METHODS

Search strategy For this systematic review, a comprehensive search was conducted using the following electronic databases: PubMed, SCOPUS, Web of Science, and SportDiscus. These databases were selected due to their extensive coverage of sports science, medical, and rehabilitation literature.

The search strategy involved a combination of Medical Subject Headings (MeSH) and free-text terms relevant to the study focus. The following key terms were used:

"Reliability"
"Reproducibility"
"Rock Climbing"
"Sport Climbing"
"Boulder"
"Lead Climbing"
"Climbers"
"Finger Strength"
"Handgrip Strength"
"Dynamometer"
These terms were combined with Boolean operators (AND, OR) to ensure a thorough and inclusive search for studies that assessed the validity and reliability of finger strength measurements in climbers.

We will perform a comprehensive search across multiple electronic databases in [mes/año] to identify studies that assess the validity and reliability of finger strength testing methods in climbers. The following databases will be used: PubMed, Scopus, Web of Science, and SportDiscus. The search terms will include: "Reliability" OR "Reproducibility" AND "Rock Climbing" OR "Finger Strength" OR "Handgrip Strength" OR "Dynamometer" AND "Test-retest" OR "Measurement".

Participant or population Climbers (amateur, advanced, and elite) of both sexes, ranging from 10 to 60 years old.

Intervention Intervention being evaluated

The interventions evaluated in this systematic review focus on various methods used to assess finger strength in climbers. These interventions involve different types of grip positions, depths of holds, and testing protocols, all of which are critical for accurately measuring the strength of the finger flexor muscles, which are essential for climbing performance. The specific interventions include:

Types of Grips:
Crimp: A grip where the fingers are bent, and the thumb presses over the index finger, providing maximum force but with increased injury risk.

Half Crimp: A more stable grip where the fingers are partially bent, commonly used during climbing and often the focus of strength tests.
Open Hand: A grip where the fingers are extended and rely on the finger pads, typically less forceful but safer for tendons.
Sloper: A grip on rounded holds, testing the climber's ability to generate force without a defined edge.
Hold Depths:
The depth of the holds used in strength tests varies from 6 mm to 40 mm, with tests often performed on wooden hangboards or adjustable edge systems. Commonly, shallower holds (e.g., 14 mm or 20 mm) are used to simulate real climbing conditions and test strength in the most challenging grip positions.
Types of Strength Tests:
Maximal Isometric Finger Strength (MIFS): In this test, climbers exert maximum force on a hold for a short, specified duration, typically between 3 to 5 seconds. These tests are often conducted on dynamometers or hangboards that measure force output in specific grip positions.
Rate of Force Development (RFD): This test measures how quickly a climber can generate maximum force, which is crucial for dynamic climbing moves.
Grip Endurance Tests: These involve holding a grip position for as long as possible or performing repetitive contractions, testing the endurance capacity of the finger flexors.
Types of Dynamometers and Measurement Devices:
Handheld Dynamometers: Devices such as the Tindeq Progressor or other specialized climbing dynamometers are used to measure maximal force output in various grip positions.
Force Plates: Some studies use platforms like the Kistler Quattro or Entralpi Force Plate to measure finger strength during grip tests on specific holds.
Wooden Hangboards: Devices like the Beastmaker or Lattice Training Board are commonly used to assess finger strength, often equipped with force sensors or integrated with dynamometers to measure force on small edges or slopers.
By evaluating the reliability and validity of these grip types, hold depths, test protocols, and devices, this review aims to identify the most effective methods for accurately assessing finger strength in climbers. The goal is to improve the standardization of these assessments to enhance both training practices and performance outcomes in climbing.

Comparator In this systematic review, the comparative interventions consist of alternative methods and devices used to assess finger strength in climbers, against which the primary interventions (such as specific grip tests using dynamometers and hangboards) will be evaluated. The review compares different protocols, grip types, hold depths, and measurement devices to determine which methods provide the most reliable and valid results. The comparators include:

Alternative Grip Types: Comparisons between different grip positions, such as crimp vs. open hand or half crimp vs. sloper, to evaluate which positions yield the most consistent and relevant measurements of finger strength.
Different Hold Depths: Hold depths, ranging from shallow (e.g., 6 mm or 14 mm) to deeper holds (e.g., 20 mm or 40 mm), are compared to assess how depth affects the accuracy and reliability of strength measurements in various testing scenarios.
Different Testing Protocols:
Maximal Isometric Finger Strength (MIFS) vs. Grip Endurance Tests: The effectiveness of maximal strength tests, where force is exerted for short durations, will be compared against endurance tests that measure sustained force over time.
Rate of Force Development (RFD): RFD tests will also be evaluated in comparison to other testing methods to determine their validity in measuring explosive strength.
Alternative Devices: Different measurement tools, such as handheld dynamometers (e.g., Tindeq Progressor) vs. force plates (e.g., Kistler Quattro or Entralpi), will be compared to determine which devices offer the most precise and reliable measurements of finger strength.
The goal of this comparison is to identify the most effective and consistent methods for assessing finger strength in climbers, which can then inform standardized testing protocols for training and performance evaluation in the climbing community.

Study designs to be included To address the objective of this systematic review, the following study designs will be included: Longitudinal studies, Randomized controlled trials, Randomized controlled trials (RCTs) and Reliability and validity studies.

Eligibility criteria Studies including climbers as participants.
Studies using a test-retest design for strength assessments.
Studies reporting an Intraclass Correlation Coefficient (ICC) as a measure of reliability.

Information sources Data will be collected from PubMed, Scopus, Web of Science, and SportDiscus.

Main outcome(s) The primary outcomes of this systematic review are focused on evaluating the reliability and validity of different methods used to assess finger strength in climbers. The outcomes will be categorized and measured as follows:

Reliability outcomes:
Test-retest reliability: The consistency of finger strength measurements when repeated under the same conditions over time. The primary effect measure will be the Intraclass Correlation Coefficient (ICC), with values interpreted as follows: below 0.5 (poor reliability), 0.5–0.75 (moderate reliability), 0.75–0.9 (good reliability), and above 0.9 (excellent reliability).
Interrater and intrarater reliability: The consistency of measurements between different testers (interrater) or the same tester across multiple sessions (intrarater), also measured by ICC.
Secondary outcomes will include the type of devices used and specific grip positions tested.

Additional outcome(s) Secondary outcomes will include the type of devices used, depth grip and specific grip position.

Data management The management of records and data for this systematic review will follow a structured and transparent process to ensure accuracy and reproducibility. The following steps will be taken to manage records and data throughout the review:
Reference management system:
All records identified through electronic database searches will be imported into a reference management software (Mendeley). This software will be used to organize references, remove duplicates, and track the inclusion/exclusion status of each study.
Duplicate studies will be identified and automatically removed before the screening process begins to ensure that each study is reviewed only once.
Screening process:
Titles and abstracts of the imported studies will be screened by two independent reviewers. A standardized screening tool will be used to assess whether each study meets the inclusion criteria. Discrepancies between reviewers will be resolved through discussion or by consulting a third reviewer.
Full-text screening will be conducted for studies that pass the initial title and abstract screening. The same process of independent review and consensus will be followed.
Data extraction:
A data extraction form will be developed to collect relevant information from each included study. This will include key details such as study design, participant characteristics, intervention type, outcome measures (reliability, validity), type of devices used, grip positions, and results.
Data will be extracted by two independent reviewers to minimize the risk of bias. Any disagreements in the extracted data will be resolved through discussion or consultation with a third reviewer.
Data storage and backup:
All extracted data will be stored in a secure, password-protected system cloud-based platform (Google Drive) to ensure it is accessible and safe.
Regular backups will be made to prevent data loss, and only authorized members of the review team will have access to the data.
Management of missing data:
If data are missing from any of the included studies, attempts will be made to contact the authors of the original studies for clarification or to obtain the missing information.
Studies with missing critical data that cannot be retrieved will be documented, and their potential impact on the review's results will be discussed in the limitations section.
Reporting and transparency:
The process of data management, including the screening, extraction, and analysis procedures, will be fully documented in the final review report to ensure transparency.
The PRISMA flow diagram will be used to visually represent the number of studies at each stage of the review process.

Quality assessment / Risk of bias analysis The quality of primary studies included in this review will be assessed using two tools: the Critical Appraisal Tool (CAT) and the QAREL (Quality Appraisal for Reliability Studies). The CAT will evaluate key aspects such as sample description, blinding, test execution, and statistical analysis, while QAREL will focus specifically on the reliability of tests, including sample representativeness, blinding, and the appropriateness of test intervals.

Each study will be scored and categorized as high, moderate, or low quality based on how well they meet the criteria. Two independent reviewers will conduct the assessments, and any disagreements will be resolved by a third reviewer. The quality of the studies will be used to determine the strength of the evidence in the review, with lower-quality studies being analyzed separately or excluded from the final conclusions.The risk of bias will be assessed using the QAREL tool for reliability studies and the Clinical Appraisal Tool (CAT) for evaluating methodological quality. Each study will be rated across multiple domains, including

sample characteristics, test administration, and statistical analysis.

Strategy of data synthesis Given the expected heterogeneity of the included studies, both in terms of study design, testing protocols, and outcome measures, a narrative synthesis will be the primary approach for analyzing the data. The steps for data analysis will include: Descriptive analysis: A detailed descriptive summary will be provided for each study, including key characteristics such as sample size, participant demographics, grip types, hold depths, devices used (e.g., dynamometers, force plates), and outcome measures related to reliability (e.g., Intraclass Correlation Coefficient, ICC) and validity (e.g., correlation with performance measures). This will provide a clear overview of the variety of methods and outcomes across the studies. Narrative synthesis: Due to the diversity of methodologies used in the included studies, a narrative synthesis will be conducted to qualitatively summarize the findings. This synthesis will focus on identifying patterns and trends across studies, such as which grip types and testing protocols (e.g., maximal isometric strength, grip endurance) show the most consistent reliability and validity. Studies will be grouped by common themes, such as type of device used, grip positions assessed, or the population tested (e.g., elite climbers, recreational climbers). This will allow for a more structured comparison and discussion of the results. Subgroup analysis: Where applicable, subgroup analyses will be performed to explore potential differences in findings across specific variables. For instance, differences in reliability outcomes based on grip type (e.g., crimp vs. open hand) or device type (e.g., dynamometer vs. force plate) will be explored. Similarly, differences in outcomes for various climber skill levels (e.g., beginner vs. elite) will also be considered. Assessment of methodological quality: The quality of the included studies, as assessed using the Critical Appraisal Tool (CAT) and the QAREL tool for reliability studies, will be taken into account when interpreting the results. Studies of low quality will be flagged, and their findings will be discussed with caution, ensuring that conclusions are drawn primarily from high-quality evidence. This approach will allow for a thorough examination of the existing literature, even in the absence of homogeneous data suitable for meta-analysis, providing meaningful insights into the reliability and validity of finger strength assessments in climbers.Data will be synthesized qualitatively due to expected heterogeneity in methods and outcomes. If appropriate, a quantitative meta-analysis will be conducted, and a random-effects model will be used to calculate the pooled estimates of reliability.

Subgroup analysis Subgroup analysis
Subgroup analyses will be conducted to explore potential variations in the reliability and validity of finger strength assessment methods across different conditions. These analyses will help identify factors that may influence the outcomes and provide more specific insights relevant to particular contexts. The planned subgroup analyses will include:

Grip type:
The review will compare the results of studies based on the type of grip used during the assessment, such as crimp, half crimp, open hand, or sloper. This analysis will evaluate whether specific grip positions yield more reliable or valid results in measuring finger strength.
Hold depth:
Studies will be grouped by the depth of the holds used during strength testing (e.g., shallow holds such as 6 mm or deeper holds like 20 mm). The analysis will assess whether hold depth affects the reliability and validity of finger strength measurements and which depths provide the most consistent outcomes.
Device type:
A comparison will be made between the different types of measurement devices used, such as handheld dynamometers, force plates, or hangboards equipped with sensors. This will allow an evaluation of how the choice of device influences the accuracy, reliability, and practical application of the strength tests.
Climber experience level:
The studies will be stratified based on the skill level of the participants (e.g., beginner, intermediate, elite climbers). This subgroup analysis will examine whether the reliability and validity of strength assessments differ across climbers with varying levels of experience, potentially highlighting which tests are more suitable for specific groups.
Testing protocol:
The review will explore differences in outcomes based on the type of strength test employed, such as maximal isometric strength tests, rate of force development (RFD), or endurance tests. This will help determine which protocols are more reliable or valid in assessing finger strength.
The results of these subgroup analyses will provide detailed insights into the factors that may influence the effectiveness of finger strength assessments, allowing for more tailored recommendations based on specific grip positions, devices, or populations.

Sensitivity analysis A sensitivity analysis will be conducted to evaluate the robustness of the findings, including studies with lower quality or those using different devices.

Language restriction Articles written in English and Spanish will be included.

Country(ies) involved The study is being carried out in Spain, where all authors are based. The lead author is Jorge Pérez-Cordero, with co-authors Diego Soto-García and Daniel Jerez-Mayorga (Chilean, working in Spain).

Keywords Reliability; Validity; Finger Strength; Climbing; Dynamometer; Performance.

Dissemination plans The dissemination of the results of this systematic review will be carried out through a structured strategy to ensure that the findings are accessible and useful to a broad audience, including researchers, professionals in the field of sports training, and climbers. The dissemination plan will include the following elements:

Publication in peer-reviewed academic journals:
The full results of the review will be submitted to an academic journal specializing in sports science, sports medicine, or exercise physiology. Publication in a peer-reviewed journal will ensure the visibility of the findings within the scientific community and provide access to researchers interested in the evaluation of finger strength and climbing performance.

Presentation at conferences and symposia:
The results will also be presented at relevant national and international conferences, such as events related to sports medicine, climbing training, or scientific conferences on strength assessment and sports performance. This will allow interaction with professionals in the field, facilitating discussion and the exchange of ideas on the practical application of the findings.
This approach will maximize the impact of the systematic review, promoting both the advancement of scientific knowledge and its practical application in the training and performance evaluation of climbers.

Contributions of each author
Author 1 - Jorge Pérez-Cordero - Led the development of this systematic review, including the design, data extraction, analysis, and drafting of the manuscript. He was responsible for the bulk of the research and writing and played a central role in interpreting the findings.

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Author 2 - Daniel Jerez-Mayorga - Contributed to the critical review of the manuscript. He/she provided important feedback on the methodology, interpretation of results, and clarity of the writing. He/she also assisted in reviewing the final draft before submission.
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Author 3 - Diego Soto García - Was involved in revising the manuscript for intellectual content. He/she helped refine the structure and argumentation of the article, ensuring that the conclusions were supported by the data presented. He/she also contributed to the final approval of the manuscript for publication.
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