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Comparative Analysis of Two Grip Strength Training Protocols in Experienced Climbers

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A boat with eight rowers and a coxswain moves with precision and synchrony during a training session on calm waters.
Adobestock ®Smuki

Abstract

The aim of this study was to compare the effects of the traditional weighted dead-hang method (HIMA) and the effects of the active pull training method using a dynamometer (PIMA). Additionally, the strength difference between hands and its evolution after the proposed protocols was analyzed. Eleven climbers were randomly divided into a Control Group, CG (n = 5) 33.20 (8.7) years, 14.40 (0.548) climbing level IRCRA, and a Dinamo Group, DG (n = 6) 31.50 (6.56) years, 14.67 (1.366) IRCRA climbing level. CG followed HIMA protocol, while DG followed PIMA protocol. The common characteristics of both groups' protocols were: 4 weeks duration, working on a 14 mm wooden strip, 3 series of dead-hang in the first week, 4 series in the second and third, and 5 series in the last week; 10 second efforts at 85% intensity, with 3-minute rests. An ANOVA analysis showed significant differences ($p \leq .05$) after training protocols for both groups in all the variables studied: the peak force, the RFD200ms, the ST, and the MHT_14. No significant differences in strength were found between hands. Despite that, active pull with a dynamometer method reduced the differences in strength values between hands after training. Both grip strength methods (PIMA and HIMA), seem to be effective for improving key factors in climbing performance. Future research should analyze the influence of both training methods with larger samples and with higher level athletes, as well as with female samples.

Keywords: dead-hang, dynamometer, finger strength, performance, sport climbing, training.

Introduction

The popularity of climbing has continued growing since the debut of the sport at the Olympic Games (Michael et al., 2019). Despite many new climbing gyms being built over the last few years (Climbing Business Journal., 2023), the increasing number of athletes suggests that new climbing centers will be opened in the future. This interest from the general population has had an impact on the emergence of new elite athletes [International federation of sport climbing (IFSC), 2025] and an increase in the number of competitions. This has led the scientific world to also become interested in the discipline and, thus, a multitude of new studies are being carried out on this sport.

The need for new research and training strategies has motivated the creation of new compact and portable devices that can be used to measure determining variables in climbing performance (Breen et al., 2023). Among these devices, force sensors stand out, such as the Progressor Tindeq (Tindeq, Trondheim Norway) (Labott et al., 2022) or Chronojump (Chronojump Boscosystem, Barcelona España) (Colomar et al., 2020; Moreno-Pérez et al., 2020). These new devices allow us to explore new forms of training based on quantitative data with high levels of validity and reliability. These methods contrast with traditional methodologies based on imprecise and subjective measurements, sometimes based on the athlete's own perception (Michailov, 2014). Sensors measure grip strength, the key performance indicator in climbing (Bergua et al., 2018; Consuegra, 2020; López-Rivera, 2014; López-Rivera & González-Badillo, 2012, 2019). Among the factors that explain the production of grip force in climbing, the maximum grip force and the Rate of Force Development (RFD) are considered the most adequate for measuring performance (Consuegra, 2020).

There are currently two main training methods to improve finger grip strength in climbers; the traditional dead-hang method conceived by Eva López (López-Rivera, 2014; López-Rivera & González-Badillo, 2012), which has been the most commonly used, and training with force sensors with active pull (Breen et al., 2023) which allows athletes to train unilaterally, even when not supporting body weight, and quantifying the load at all times. While the traditional dead-hang method involves a passive effort on the finger structures, the force sensor training method involves an active voluntary tensile effort. At the same time, the terms Holding Isometric Muscular Action (HIMA) and Push Isometric Muscular Action (PIMA) (Schaefer & Bittmann, 2017) describe two types of isometric contractions which we could relate to them respectively. In HIMA, the effort is passively supported, while in PIMA, although there is no movement, an active attempt is made to overcome resistance. Objective measures show that these two types of contractions are physiologically different (Dech et al., 2022; Oranchuk et al., 2024; Schaefer & Bittmann, 2021) which makes both types of training different.

Even though few studies look at the differences between both types of contractions, it has been suggested that HIMA could be used for injury prevention and rehabilitation, while PIMA could be a better option for prolonged activations and for stimulating agonist adaptations (Oranchuk et al., 2024).

It is for these reasons that studying the differences between both methods in the sport performance framework seems particularly relevant. Additionally, climbing has traditionally used a grip strength training protocol following HIMA's characteristics (traditional dead-hang method) which makes studying the differences between both HIMA and PIMA protocols more interesting for this sport.

Therefore, the present study aimed to compare the effects of two different grip strength training methods (traditional weighted dead-hang as a HIMA, and force-sensing active pulls as a PIMA) on key markers of climbing performance: peak grip strength, RFD200ms, strength test (ST), and maximum dead-hang time (MHT_14). The secondary aim was to analyze the differences in peak strength of each hand and to analyze the differences after training.

We hypothesized that both training methods would be effective in improving all the key factors in climbing performance studied (peak grip strength, RFD200ms, ST, and MHT_14); but grip strength training through the active method using the Chronojump device would present better results.

For our second aim, we hypothesized that the dynamometer training method, not being bilateral, would help reduce the differences in strength between hands after the training period.

Methods

Participants

Twenty climbers training twice per week participated in this study. The inclusion criteria are shown in Table 1. Finaly eleven climbers could finish the protocol.

The sample was divided into two groups using stratified random sampling, based on self-determined climbing level. Main anthropometric and training characteristics are depicted in Table 2. Every climber in our sample self-identified as either boulderer or lead climber. The IRCRA scale (Draper et al., 2015) was used to determine the level of climbing.

The study sessions took place on Monday and Wednesday afternoons at the same time, after which the participants attended their guided climbing sessions. They carried out identical sessions with the same climbing trainer, who focused the sessions on maximum strength work, in accordance with the objectives of the study.

The participants were informed of the procedure through an informative email and signed a consent form. The study was designed in compliance with the recommendations for clinical research of the Declaration of Helsinki and approved by the Ethics Committee of the University (Universidad Europea de Madrid, CIPI/23.105).

Participants were asked to:

- Attend all protocol training sessions.
- Do not modify their sports habits related to climbing.
- Refrain from any intense physical activity 24h before the test sessions.

The study took place from May to July 2023.

Table 1
Inclusion criteria defined

Have at least 2 years of climbing experience.
Be free of injuries that prevent the participant from following the study protocol.
Have been part of the climbing group for at least the last 3 months.
Have previous training experience in dead-hang exercises.
Be at least 18 years old.
Be able to attend all protocol training sessions.

Note. Own elaboration.

Table 2
Main characteristics of the sample and of each of the groups, mean and standard deviation

Characteristics	Total, *n* = 11	CG, *n* = 5	DG, *n* = 6
Age (years)	32.27 (±7.29)	33.20 (±8.701)	31.50 (±6.56)
Sex (no. men)	9	4	5
Body mass (kg)	66.66 (±12.51)	70.42 (±14.570)	63.533 (±10.841)
Height (m)	1.73 (±0.087)	1.748 (±0.086)	1.715 (±0.093)
BMI (kg/m^2)	22.12 (±3.01)	22.907 (±3.681)	21.475 (±2.489)
Best redpoint (IRCRA)	14.55 (±1.036)	14.40 (±0.548)	14.67 (±1.366)
Climbing experience (years)	5.045 (±3.274)	5.40 (±2.793)	4.75 (±3.869)
Training group experience (years)	3.954 (±2.987)	3.80 (±1.483)	4.083 (±4.005)
Self-identified discipline (no. boulderer)	8	2	6

Note. CG: control group; DG: dynamometer group; BMI: body mass index (kg/m^2); best redpoint grade in the past three months; IRCRA: International Rock-Climbing Research Association.

Table 3
Warm-up prior to testing and training for both CG and DG

Joint mobility, paying special attention to the upper body: fingers, wrists, elbows, shoulders, back and neck.
Exercises with little volume and intensity of the main muscle groups of the upper body: exercises with bands for triceps, biceps, shoulder rotators and pectorals, dips, abdominals and tractions.
Gentle and progressive climbing distributed to the athlete's liking. 70-80 movements.
Latest movements of the wall prioritizing the use of progressively smaller holds.
3 series of dead-hang at increasing intensity from largest to smallest edges until reaching 14 mm. Dead-hangs of 10-20 seconds. Intensity determined by the size of the edge.

Note. Own elaboration.

Procedures

The intervention consisted of 4 weeks of training, with 2 training sessions per week. A familiarization session with the Chronojump device was also held, along with two evaluation sessions: one prior to and one after the training period. The warm-up was the same for both groups, and it is described in Table 3, in line with previous warm-ups used in research (Hermans et al., 2022; López-Rivera, 2014; Pérez, 2021).

Two training protocols were used: maximum passive weighted dead-hang (HIMA) for the control group (CG); and unilateral active pulls with a force sensor (PIMA) for the dynamometer group (DG).

The common characteristics for both protocols were the following:

- A 14 mm thick wooden edge was used (Bergua et al., 2018; López-Rivera, 2014).
- The series were distributed as follows: 3 series in the first week, 4 series on the second and third weeks, and 5 series on the last week; with 3-min rests between series.
- Using a half-crimp or open-crimp type of grip (Bergua et al., 2018; Quaine & Vigouroux, 2004) was allowed throughout the study.

The specific characteristics of the HIMA protocol were the following:

- An intensity of 85% (Devise et al., 2022; López-Rivera, 2018; Pérez, 2021) calculated from the total weight (adding loaded weight + body weight) measured on the pre-assessment.
- The series consisted of 10-second weighted dead-hang efforts with two hands, as described in Eva López's maximum dead-hang method (López-Rivera, 2014; López-Rivera & González-Badillo, 2012).
- The grip and placement instructions described by Baláš et al. (2014); y Michailov et al. (2018) were followed.

The specific characteristics of the PIMA protocol were the following:

- An intensity of 85%(Devise et al., 2022; López-Rivera, 2018; Pérez, 2021) calculated from the maximum newtons measured on the pre-assessment.
- The series consisted of 10-second pull efforts with unilateral maintained pull with dynamometer (Baláš et al., 2012; Rokowski et al., 2021).
- The grip and placement instructions described by Giles et al. (2021) were followed.

Both groups performed the same test for the pre- and post-assessment.

The order of the tests used for the evaluation was as follows: MHT_14, ST, and Maximal force peak and RFD. There were 5-min rests between every test.

Chalk was allowed during testing, and the edge was brushed between participants.

MHT_14: Maximum hanging time with both hands (Bergua et al., 2018) measured on a 14 mm thick wooden edge, until the climber lost contact of any finger with the hold, flexed their arms or hips, or extended their shoulders. Only one measurement was made (Hermans et al., 2022).

ST: Maximum added weight that was supported in dead-hang with both hands for 5 s (López-Rivera & González-Badillo, 2012, 2019) measured in a 14 mm thick wooden edge. The maximum weight supported was found through the minimum number of attempts, and rests of a minimum of 3 min were allowed between each attempt. ST was used to calculate the CG training loads, 85% of the maximum weight (adding loaded weight + body weight).

Table 4
Specifications of the force sensor used, Chronojump Boscosystem

Max capacities	500 kg
Output impedance	350 ± 3 Ohm
Isolation resistance	More than 2000 cc
Input impedance	365 ± 5 Ohm
Weight	638 g
Digital-Analog Converter	
Resolution	24 bits
Frequency	160 hHz
Trigger Input (short circuit detector)	RCA

Note. Own elaboration based on the information provided in Chronojump Boscosystem, (n.d.).

Peak force and RFD with each hand: Measured with the dynamometer through a maximum pull (maximum voluntary contraction) (Levernier & Laffeye, 2019). After the sentence "pull as fast and hard as you can" (Maffiuletti et al., 2016), and with a countdown, each participant recorded the maximum force value and RFD200ms they could. 3 attempts were made with 1 min of rest between them. From the average force values recorded, the loads for each hand were adjusted for the dynamometer group; calculating 85% of the newtons achieved and rounding to the nearest ten.

The maximum value of peak force (Hermans et al., 2022), the average of the 3 attempts, as well as the average of the RFDs (Maffiuletti et al.,2016) were recorded.

A 5-min rest period was allowed between each test and after warm-up.

The dynamometer used was Chronojump Boscosystem, which has been validated (de Blas et al., 2012) and even used to validate other instruments (Gaudet & Handrigan, 2020). The main characteristics of the instrument are shown in Table 4.

Before using the device, it was calibrated, as described in the user manual (Foix & Padull, 2021).

The device software Chronojump Boscosystem version 2.3.0 was used for data collection and analysis. The software is free to download on its website.

To extract the values of maximum force and RFD200ms, the modeled function offered by the software was used, thus ensuring that the values varied less between each of the measurements (Pérez; 2021). To calculate the data, the initial point was used as the one at which the tangent of the maximum RFD intersected the x axis; and as a final point the one suggested by the application, which corresponds to the moment in which the maximum force is stable for 1 s. With this procedure, valid data is obtained in which the error is less than 5%.

Statistical Analysis

The statistical analysis was performed with the data analysis package SPSS for Windows version 27.0; IBM, Armonk, NY, USA. A study of the sample was carried out through several descriptive statistics functions, such as the mean and standard deviation.

Regarding the data obtained during the study (PRE and POST measurements of the dependent variables described in the previous section), the means obtained from all the measurements carried out were used, which were 3 in all cases except for the ST and MHT_14 tests, where only a single measurement was used, the one with the highest values. The assumptions of normality were tested with the Shapiro-Wilk test.

Once the normality of each of the groups into which the sample was divided was confirmed, a two-factor mixed ANOVA test was used (Table 5); proposing time as an intra-participant factor (PRE and POST tests) and groups (CG and DG) as an inter-participant factor. With this test it was possible to compare the effect of the type of training, the difference between groups and the interaction between the type of training and the difference between groups. The effect size was assessed by the eta squared value (η^2) as specified in previous research (Fritz et al., 2012). The effect size was determined based on the values recommended in the article by Cárdenas Castro & Arancibia Martini (2014); establishing a small effect $\eta^2 = .01$, a medium effect $\eta^2 = .06$, and a great effect $\eta^2 = .14$.

The Bonferroni post hoc test was performed to analyze the pairwise comparisons. The level of significance for all comparisons was set at $p \leq .05$.

As a secondary analysis, the difference in strength between hands was studied through a T-test for paired samples. The evolution of these differences depending on the training method used was also studied, using the difference between the means of both hands.

Results

The effect of the type of training, the difference between groups and the interaction between the type of training and the difference between groups is shown in Table 5.

Significant differences have been found between PRE and POST results for all variables (all tests) and for all groups. We observed a medium to large effect size in the MHT_14 tests (.242) and in the peak force measurement for the non-dominant hand (.081). Small to medium effect sizes were observed for the ST tests (.034), and for the peak force measurement for the dominant hand (.045). The effect sizes on the RFD measurements for the dominant and nondominant hand were very small (.001 and.008 respectively). The comparison of the peak force and RFD of the dominant and non-dominant hand, for each training group and PRE and POST training is shown in Table 6.

No significant differences were found in any of the analyses carried out regarding the differences between hands. Despite not finding significance, the difference between hands was 5.52% in the PRE tests and 3.90% in the POST tests, for the general sample. The dominant hand obtained better results in all tests, except in RFD PRE.

Table 5
Results obtained in each of the interventions, PRE and POST, for each of the groups, CG and DG

	CG				DG				Results		
	PRE		POST		PRE		POST				
	M	SD	M	SD	M	SD	M	SD	F	*p*	η^2
ST (kg)	6.20	4.550	15.40*	3.847	19.50‡	7.450	21.17*‡	9.326	0.317	.587	.034
MHT_14 (s)	11.80	6.648	23.00*	6.000	33.00‡	16.793	39.50*	15.476	2.879	.124	.242
Average Peak Force DH (N)	319.737	24.544	372.106*	47.018	362.296	90.105	431.982*	107.598	0.421	.533	.045
Average Peak Force NDH (N)	316.219	53.877	364.438*	69.615	331.408	65.187	409.924*	91.387	0.797	.395	.081
Average RFD DH (N/s)	456.633	113.854	601.533*	120.886	579.066	218.798	719.411*	226.868	0.006	.939	.001
Average RFD NDH (N/s)	511.806	147.433	625.900*	122.776	545.155	104.378	678.277*	164.206	0.071	.796	.008

Note. Own elaboration based on the information obtained. CG: control group; DG: dynamometer group; M: mean; SD: standard deviation; F: Fisher-Snedecor test; n2 (format correcte de la n): eta squared value; RFD as RFD200m.
* Significant differences between pre-tests and post-tests ($p \leq .05$).
‡ Significant differences between CG and DG ($p \leq .05$).

Table 6
Results obtained from the T test for related samples in the comparison of different variables depending on the hand used. Analysis carried out on the total sample and by groups

	Total sample				CG				DG			
	M	SD	*p*	ES	M	SD	*p*	ES	M	SD	*p*	ES
PF PRE (DH - NDH) (N)	18.447	40.853	.165	0.434	3.518	39.403	.852	0.081	30.888	41.075	.125	0.694
PF POST (DH – NDH) (N)	15.514	36.420	.188	0.410	7.668	40.012	.690	0.173	22.052	35.485	.188	0.573
RFD PRE (DH – NDH) (N/s)	-6.581	108.991	.845	-0.058	-55.173	65.729	.134	-0.758	33.911	126.385	.540	0.248
RFD POST (DH – NDH) (N/s)	11.360	81.427	.653	0.134	-24.366	50.776	.344	0.694	41.133	94.118	.333	0.403

Note. Own elaboration based on the information obtained. CG: control group; DG: dynamometer group; M: mean; SD: standard deviation; ES: effect size expressed as Hedges correction (uses the sample standard deviation of the mean difference, plus a correction factor); PF: Peak Force; RFD as RFD200ms; DH: dominant hand; NDH: non-dominant hand. Significance level set at 95%.

Discussion

The main objective of the present study was to compare the effects of two different methods of grip strength training (traditional dead-hang training, HIMA, and active pull training with dynamometer, PIMA), on key performance indicators in climbing: peak grip strength, RFD, ST, and MHT_14.

The main hypothesis was fulfilled. Both trainings, traditional dead-hang training and active pull training with a dynamometer; are effective in significantly improving all the key markers in climbing performance (peak grip strength, ST, MHT_14, and RFD).

Results hint at better outcomes using the active pulling training methods but we should be cautious about the generalization of these results given the size of the sample used. We observed a medium to large effect size in the MHT_14 tests (0.242) and in the peak force measurements for the non-dominant hand (.081). A larger sample could provide more information which could follow the trend we see in these results, or not, elucidating this subject.

The secondary objective of this work was to analyze the differences in peak strength of each hand and see how these differences evolve with each of the training sessions. We hypothesized that grip strength training through the active method using the Chronojump device would present better results. This hypothesis was not fulfilled, since we did not find POST differences between training groups.

Regarding the data obtained in the study, both training methods have been effective in improving the key markers of climbing performance studied in 4 weeks. As has been previously studied (Devise et al., 2022; Levernier & Laffeye, 2019; López-Rivera & González-Badillo, 2012) a 4-week exercise program is sufficient to observe improvements in grip strength. With regard of improvements in peak strength, the study by Levernier & Laffeye (2019) used one-handed dead-hang training; and observed improvements only with one type of grip and one of the hands. These improvements are smaller than those found in the present study. This may be due to the shorter duration of the dead-hangs (around 6 s), or a higher sample level (national and international climbers).

In the study by Hermans et al. (2022) they used dead-hang training, and found significant differences in peak force, like the present study. Participants performed shorter dead-hang training (7 s) with shorter rests (3 s) within the same series. In this case the intervention was 10 weeks, with a sample level starting at score 11 on the IRCRA scale. Peak strength is measured in a pull-up position with arms flexed at 90º. In another study (Devise et al., 2022) a dynamometer was used for both testing and training, but the pull training was performed with two hands. If we look at the results obtained at the intensities closest to those of the present study (between 80% and 100%), significant improvements in peak force are observed, as in the present study.

Regarding the improvements in RFD, in the study by Levernier & Laffeye (2019) and by Hermans et al. (2022) significant improvements are observed, in line with the results obtained. Hermans et al. (2022) analyzed maximum time in dead-hang with a larger edge, 23 mm, and significant improvements are found, as in the present investigation. In the study by Devise et al. (2022) resistance was measured with a different protocol than the one we used, making it difficult to compare their results with those obtained in our research.

Considering the levels of force between hands, in the present study no significant differences were found. Despite the lack of significant differences, the dominant hand was the one that presented higher levels for all tests except for the RFD PRE measurements. The dominant hand obtained an extra 5.52% of peak force in the PRE measurements, and 3.90% in the POST measurements, compared to the non-dominant hand. In the article by Vujic et al. (2021) no significant differences were found between the hands either, and these differences were less than 10%. In this case, higher levels of force were also recorded for the dominant hand. In the article by Levernier & Laffeye (2019), no significant differences were found between hands, and the right hand continued to record higher values in all grips except the extension grip.

In both studies, mean grip strength values higher than in the present study (320–380N) were recorded. In the study by Vujic et al. (2021), values of approximately 550–580N per hand were recorded, with a sample at levels 14–15 on the IRCRA scale, and in the study by Levernier and Laffaye (2019), values of 410–460N were recorded, with a sample at levels 24–26. Both studies obtained measurements using a manual dynamometer. These differences could be explained by the level differences between samples (Assmann et al., 2021), as well as the different ways of calculating force levels. It has been observed that these values vary depending on the surface and depth. (Bergua et al., 2018).

Regarding the secondary hypothesis of the work "dynamometer training, since it is not bilateral, helps to reduce the differences between hands"; the data seems to confirm the proposed hypothesis, but the results must be interpreted with caution. It is a superficial analysis in which only the differences in PRE and POST means between the two proposed interventions have been analyzed. Furthermore, the differences found are small.

In the study by Levernier & Laffeye (2019), a trend to increase the differences between hands with open grip after training was observed. In this case, the training followed is not bilateral but uses instead dead-hang, not active pull training. The results show no significant differences (less than a 10% difference) between hands in intermediate-high level climbers, although the right hand tends to present higher strength values. Regarding the proposed hypothesis, although the data from the present study suggest that active pull training with a non-bilateral dynamometer could help reduce differences between hands, the results are not conclusive, and more research would be necessary.

Conclusions

In response to the main objective, it is concluded that both grip strength training with active pulls and traditional dead-hang training seem to be effective methods to improve key factors in climbing performance in an intermediate level sample. Improvements in grip strength depend on both, the method (active pull or traditional dead-hang) and the established protocol (dead-hang time, intensity...).

In response to the secondary objective, it is concluded that the strength differences between the dominant and non-dominant hand decrease after applying non-bilateral active pulling training with a dynamometer. In the sample of the present study, as well as in the samples of the other studies analyzed, non-significant differences (less than 10%) are observed between the strength levels of each hand.

It should be noted that no studies have been found that compare the results of the two proposed protocols, and there are few articles in the scientific literature that propose interventions with exercises in climbing. Those that exist use very different training methods and systems, which makes it very complex to compare the results obtained across different articles.

As a practical application, climbing trainers could use this knowledge to improve their athletes' grip strength in as little as 4 weeks.

Furthermore, this study suggests that using a force cell, specifically the Chronojump device, helps coaches quantify training load at all times, allowing customization of training for climbers to get the best out of their training time.

Limitations of the study

One of the main limitations of the study was the small size of the sample. This prevented us from drawing generalizations from the results we obtained, such as the differences between hands. Another drawback was the relatively low climbing level of the participants, which may have affected the improvements observed. However, the difficulty of recruiting advanced climbers willing to undertake a 4-week experimental study should be taken into account.

Additionally, more information related to the climbing habits of the participants could have been collected.

Future Research

Future lines of research should consider analyzing the two methods through larger samples of a higher climbing level to better explore these results, especially the effects of both methods in the differences between hands. Furthermore, some could focus on studying the differences through a larger female sample. Finally, comparing climbers from different disciplines like bouldering and sport climbing could be of interest.

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References

Assmann, M., Steinmetz, G., Schilling, A. F., & Saul, D. (2021). Comparison of Grip Strength in Recreational Climbers and Non-Climbing Athletes—A Cross-Sectional Study. *International Journal of Environmental Research and Public Health*, *18*(1), 129. https://doi.org/10.3390/ijerph18010129

Baláš, J., Michaela, P., Jan, K., Cochrane, D. J., & Martin, A. J. (2014). The role of arm position during finger flexor strength measurement in sport climbers. *International Journal of Performance Analysis in Sport*, *14*(2), 345–354. https://doi.org/10.1080/24748668.2014.11868726

Baláš, J., Pecha, O., Martin, A. J., & Cochrane, D. (2012). Hand-arm strength and endurance as predictors of climbing performance. *European Journal of Sport Science*, *12*(1), 16–25. https://doi.org/10.1080/17461391.2010.546431

Bergua, P., Montero-Marin, J., Gomez-Bruton, A., & Casajús, J. A. (2018). Hanging ability in climbing: an approach by finger hangs on adjusted depth edges in advanced and elite sport climbers. *International Journal of Performance Analysis in Sport*, *18*(3), 437–450. https://doi.org/10.1080/24748668.2018.1486115

de Blas, X., Padullés, J. M., López del Amo, J. L., & Guerra-Balic, M. (2012). Creation and Validation of Chronojump-Boscosystem: A Free Tool to Measure Vertical Jumps. *Revista Internacional de Ciencias del Deporte*, *8*, 334–356. https://doi.org/10.5232/ricyde2012.03004

Breen, M., Reed, T., Nishitani, Y., Jones, M., Breen, H. M., & Breen, M. S. (2023). Wearable and Non-Invasive Sensors for Rock Climbing Applications: Science-Based Training and Performance Optimization. *Sensors*, *23*(11). https://doi.org/10.3390/s23115080

Cárdenas Castro, M., & Arancibia Martini, H. (2014). Potencia estadística y cálculo del tamaño del efecto en G*Power : complementos a las pruebas de significación estadística y su aplicación en psicología. *Salud y Sociedad*, *5*(2), 210–244. https://doi.org/10.22199/S07187475.2014.0002.00006

Chronojump Boscosystem. (n.d.). *Kit sensor de fuerza*. Retrieved June 21, 2023, from https://chronojump.org/es/product/kit-sensor-de-fuerza-con-accesorios/

Climbing Business Journal. (2023). *Gyms and Trends 2023.* https://www.climbingbusinessjournal.com/gyms-and-trends-2023/

Colomar, J., Baiget, E., & Corbi, F. (2020). Influence of Strength, Power, and Muscular Stiffness on Stroke Velocity in Junior Tennis Players. *Frontiers in Physiology*, *11*, 1–9. https://doi.org/10.3389/fphys.2020.00196

Consuegra, S. (2020). *Entrenamiento de escalada basado en la evidencia científica*. Desnivel.

Dech, S., Bittmann, F. N., & Schaefer, L. V. (2022). Muscle oxygenation and time to task failure of submaximal holding and pulling isometric muscle actions and influence of intermittent voluntary muscle twitches. *BMC Sports Science, Medicine and Rehabilitation*, *14*(1), 1–10. https://doi.org/10.1186/s13102-022-00447-9

Devise, M., Lechaptois, C., Berton, E., & Vigouroux, L. (2022). Effects of Different Hangboard Training Intensities on Finger Grip Strength, Stamina, and Endurance. *Frontiers in Sports and Active Living, 4*. https://doi.org/10.3389/fspor.2022.862782

Draper, N., Giles, D., Schöffl, V., Konstantin Fuss, F., Watts, P., Wolf, P., Baláš, J., Espana-Romero, V., Blunt Gonzalez, G., Fryer, S., Fanchini, M., Vigouroux, L., Seifert, L., Donath, L., Spoerri, M., Bonetti, K., Phillips, K., Stöcker, U., Bourassa-Moreau, F., Garrido, I., Drum, S., Beekmeyer, S., Ziltener, J.L., Taylor, N., Beeretz, I., Mally, F., Amca, A.M., Linhart, C. & Abreu, E. (2015). Comparative grading scales, statistical analyses, climber descriptors and ability grouping: International Rock Climbing Research Association position statement. *Sports Technology*, *8*(3–4), 88–94. https://doi.org/10.1080/19346182.2015.1107081

Foix, B., & Padull, X. (2021). *Manual de Chronojump*. https://chronojump.org/docs/chronojump_manual_es.pdf

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology: General*, *141*(1), 2–18. https://doi.org/https://doi.org/10.1037/a0024338

Gaudet, J., & Handrigan, G. (2020). Assessing the Validity and Reliability of A Low-Cost Microcontroller-Based Load Cell Amplifier for Measuring Lower Limb and Upper Limb Muscular Force. *Sensors (Switzerland)*, *20*(17), 4999. https://doi.org/10.3390/s20174999

Giles, D., Hartley, C., Maslen, H., Hadley, J., Taylor, N., Torr, O., Chidley, J., Randall, T., & Fryer, S. (2021). An All-Out Test to Determine Finger Flexor Critical Force in Rock Climbers. *International Journal of Sports Physiology and Performance*, *16*(7), 942–949. https://doi.org/10.1123/ijspp.2020-0637

Hermans, E., Saeterbakken, A. H., Vereide, V., Nord, I. S. O., Stien, N., & Andersen, V. (2022). The Effects of 10 Weeks Hangboard Training on Climbing Specific Maximal Strength, Explosive Strength, and Finger Endurance. *Frontiers in Sports and Active Living*, *4*, 1–10. https://doi.org/10.3389/fspor.2022.888158

International federation of sport climbing (IFSC). (2025). National Federations Quotas 2025 IFSC season. *International Federation of Sport Climbing (IFSC)*, 1–3.

Labott, B. K., Held, S., Wiedenmann, T., Rappelt, L., Wicker, P., & Donath, L. (2022). Validity and Reliability of a Commercial Force Sensor for the Measurement of Upper Body Strength in Sport Climbing. *Frontiers in Sports and Active Living*, *4*. https://doi.org/10.3389/fspor.2022.838358

Levernier, G., & Laffeye, G. (2019). Four Weeks of Finger Grip Training Increases the Rate of Force Development and the Maximal Force in Elite and Top World-Ranking Climbers. *Journal of Strength and Conditioning Research*, *33*(9), 2471–2480. https://doi.org/10.1519/JSC.0000000000002230

López-Rivera, E. (2014). *Efectos de Diferentes Métodos de Entrenamiento de Fuerza y Resistencia de agarre en escaladores deportivos de distintos niveles.* Universidad de Castilla-La Mancha.

López-Rivera, E. (2018). Guía de Entrenamiento de Suspensiones (III). Pautas y Planificación para SuspMax, Suspint y SuspSub y Ejemplos de Planning para SuspMax. *Eva López. Entrenamiento Personal en Escalada Deportiva.* https://eva-lopez.blogspot.com/2018/06/guia-de-entrenamiento-de-suspensiones-III-planificacion-y-planes-SubMax.html

López-Rivera, E., & González-Badillo, J. J. (2012). 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 Technology*, *5*(3–4), 100–110. https://doi.org/10.1080/19346182.2012.716061

López-Rivera, E., & González-Badillo, J. J. (2019). Comparison of the Effects of Three Hangboard Strength and Endurance Training Programs on Grip Endurance in Sport Climbers. *Journal of human kinetics, 66, 183–195*. https://doi.org/10.2478/hukin-2018-0057

Maffiuletti, N. A., Aagaard, P., Blazevich, A. J., Folland, J., Tillin, N., & Duchateau, J. (2016). Rate of force development : physiological and methodological considerations. *European Journal of Applied Physiology*, *116*, 1091–1116. https://doi.org/10.1007/s00421-016-3346-6

Michael, M. K., Witard, O. C., & Joubert, L. (2019). Physiological demands and nutritional considerations for Olympic-style competitive rock climbing. *Cogent Medicine*, *6*(1), 1667199. https://doi.org/10.1080/2331205x.2019.1667199

Michailov, M. (2014). Workload characteristics, performance limiting factors and methods for strength and endurance training in rock climbing. *Medicina Sportiva*, *18*(3), 97–106. https://doi.org/10.5604/17342260.1120661

Michailov, M. L., Baláš, J., Tanev, S. K., Stoyanov, H., Kodejška, J., & Brown, L. (2018). Reliability and Validity of Finger Strength and Endurance Measurements in Rock Climbing Reliability and Validity of Finger Strength and Endurance Measurements in Rock. *Research Quarterly for Exercise and Sport*, *89*(2), 246–254. https://doi.org/10.1080/02701367.2018.1441484

Moreno-Pérez, V., Méndez-Villanueva, A., Soler, A., Del Coso, J., & Courel-Ibáñez, J. (2020). No relationship between the nordic hamstring and two different isometric strength tests to assess hamstring muscle strength in professional soccer players. *Physical Therapy in Sport*, *46*, 97–103. https://doi.org/10.1016/j.ptsp.2020.08.009

Oranchuk, D. J., Nelson, A. R., Lum, D., Natera, A. O., Bittmann, F. N., & Schaefer, L. V. (2024). 'Pushing' versus 'holding' isometric muscle actions; what we know and where to go: A scoping and systematic review with meta-analyses. *MedRxiv*. https://doi.org/10.1101/2024.11.04.24316609

Pérez, J. (2021). *Efectos de una intervención de 12 semanas para la mejora del rendimiento en escalada en bloque*. Universidad Politécnica de Madrid.

Quaine, F., & Vigouroux, L. (2004). Maximal Resultant Four Fingertip Force and Fatigue of the Extrinsic Muscles of the Hand in Different Sport Climbing Finger Grips. *Int J Sports Med 2004, 25*(8): 634–637. https://doi.org/10.1055/s-2004-821117

Rokowski, R., Michailov, M., Maciejczyk, M., Więcek, M., Szymura, J., Draga, P., Trendafilov, P., & Szygula, Z. (2021). Muscle strength and endurance in high-level rock climbers. *Sports Biomechanics*, *23*(8), 1057–1072. https://doi.org/10.1080/14763141.2021.1916577

Schaefer, L. V., & Bittmann, F. N. (2017). Are there two forms of isometric muscle action? Results of the experimental study support a distinction between a holding and a pushing isometric muscle function. *BMC Sports Science, Medicine and Rehabilitation*, *9*(1), 1–13. https://doi.org/10.1186/s13102-017-0075-z

Schaefer, L. V., & Bittmann, F. N. (2021). Paired personal interaction reveals objective differences between pushing and holding isometric muscle action. *PLOS ONE*, *16*(5 May), 1–21. https://doi.org/10.1371/journal.pone.0238331

Vujic, S., Mirkov, D., Dikic, N., Küpper, T., Totic, S., Djokovic, A., Radivojevic, N., Andjelkovic, M., Oblakovic, B. J., Baralic, I., & Manovski, K. (2021). Anthropometric, Strength, Endurance and Flexibility Characteristics of Male Elite Ice Climbers and Sport Climbers. *Deutsche Zeitschrift Fur Sportmedizin*, *72*(2), 75–80. https://doi.org/10.5960/dzsm.2020.452

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