ORIGINAL ARTICLE

TRENDS in
Sport Sciences
2022; 29(**1**): 13-17
ISSN 2299-9590
DOI: 10.23829/TSS.2022.29.1-2

Comparison of power, force, velocity and one repetition maximum of pull-ups performed by climbers on portable holds and a fingerboard

KRZYSZTOF JACEK SAS-NOWOSIELSKI

Academy of Physical Education, Institute of Sports Sciences, Katowice, Poland

Abstract
Introduction. Climbing requires a great variety of movement and manoeuvres, many of which are based on the action of pulling the body up against the force of gravity. For this reason, pull-ups are among the most commonly performed exercises to develop upper body strength and power. However, since the traditional horizontal bar is not grasped as are climbing holds, climbers use more specific devices such as fingerboards and portable holds, the latter suspended from the bar. Aim of Study. This study was designed to investigate whether there was a difference in movement velocity, power and force, as well one repetition maximum (1RM) when pulling up on fingerboards or portable holds. Material and Methods. Sixteen male climbers volunteered to participate in the study (height: 176.4 ± 7.0 cm; weight: 72.4 ± ± 11.2 kg; age: 37.0 ± 10.0 years). Subjects performed pull-ups in the fingerboard (offering a stable suspension point) or portable holds (with single-point suspension offering freedom to move in different directions of the horizontal plane). Movement parameters (power, force, velocity of pull-ups) as well as estimated 1RM were recorded using a Gyko inertial sensor. Results. The analyses revealed that the maximum values of force, power and velocity of pull-ups were not significantly different between both devices. However, values for one maximum repetition were higher on the fingerboard than on portable holds ($p < 0.001$, $\eta^2 = 0.71$). Conclusions. On the basis of the study results we can assume that fingerboards (fixed in a stable way) may be relevant in developing maximal strength in pull-ups.

KEYWORDS: strength, power, climbing, portable holds, fingerboard, pull-ups.

Received: 27 September 2021
Accepted: 8 November 2021

Corresponding author: k.sas-nowosielski@awf.katowice.pl

Introduction

Rock and sport climbing are steadily increasing in popularity, with the latter being included in the programmes of the Olympic Games in Tokyo 2020 and Paris 2024. As a sport discipline, climbing involves three events: Lead, Speed and Bouldering. While physiological requirements are slightly different in each of them, all require forceful muscle contractions to move the climber's body upward on the wall [11]. For this reason, strength training takes a prominent place in the fitness preparation of sports climbers, covering the entire spectrum of movement speeds: from static and slow strength to explosive strength. It is especially true for the muscles of the upper body, in which various types of pull-ups are of particular importance, mainly performed on fingerboards. This device is a climbing-specific device designed to facilitate exercises such as pull-ups, dead hangs, lock-offs or front levers while simulating the gripping action of fingers on holds during climbing. Recent years have seen a rapid increase in the variety and number of such devices, among which portable holds, typically with a flexible single point suspension, have become particularly popular. They make it possible to perform very similar or even identical exercises as fingerboards, stimulating the same muscle groups and movement patterns as traditional fingerboards. Still, in contrast to the former they do not offer a stable hand-holding point, but provide the freedom to move in practically all directions in the horizontal plane. Theoretically, this situation presents a slightly different challenge in terms of intra- and intermuscular coordination, thus offering to some extent at least a different stimulus situation. However, to date few studies have addressed these issues. Those conducted so far have discussed the assessment of muscle electromyographic activity in various types of pull-ups, but not in the context of exercises that take into account the specificity of climbing training. For example, Snarr et al. [14] compared the EMG activity of the major muscles involved in the body pull-up movement, i.e. the latissimus dorsi, posterior deltoid, middle trapezius, and biceps brachii. Three variations of this exercise were compared: traditional pull-ups on a horizontal bar, pull-ups on a suspension device, and pull-ups on towels hanging over a bar. They found only one difference between these conditions with lower muscle activity of the middle trapezius while performing towel pull-ups compared to the traditional pull-up. In another study, Dickie et al. [4] compared muscle activity during pull-ups performed in the supinated grip, pronated grip, neutral grip and on ropes hanging over the bar, finding differences only between the concentric and eccentric phases of each pull-up.

However, the research mentioned above has limited applicability to the specifics of climbing training. Grabbing a bar, a towel or a rope differs from grasping climbing holds. This element is one of the factors determining whether an exercise meets the principle of climbing training specificity. It is achieved through such training means as fingerboards, which enable hand positions very similar to those, which climbers encounter in real climbing situations. Depending on how they are attached, they can offer either a stable or unstable hang point, which modifies the exercise conditions to simulate exercises performed either on a stable or unstable surface. While the effectiveness of performing different types of exercises depending on the type of surface (unstable vs. stable) has been the subject of research conducted by various authors [1, 2, 8, 10], to date few studies have investigated the effectiveness of pulling exercises on a stable or unstable suspension point [4, 14]. Additionally, to our best knowledge no research has been conducted in the context of training climbers.

Knowledge concerning such conditions is becoming increasingly crucial for climbers given new trends in the construction of routes for competitions, which require climbers to have a wide range of skills and motor abilities, from maximum strength to rate of force development and power. Although climbing requires a great variety of movement and manoeuvres, many of them are based on the action of pulling the body up against the force of gravity. For this reason, pull-ups are among the most commonly performed exercises to develop upper body strength and power. However, since the traditional horizontal bar is not grasped as climbing holds are, climbers use more specific devices such as fingerboards and portable holds, the latter suspended from the bar. This study aimed to investigate a potential difference in movement velocity, power and force, as well one repetition maximum (1RM) when pulling up on a fingerboard or on portable holds.

Material and Methods

Sixteen male climbers volunteered to participate in the study (height: 176.4 ± 7.0 cm; weight: 72.4 ± ± 11.2 kg; age: 37.0 ± 10.0 years). Their climbing level ranged from 6b+ to 8c max RP, and after conversion to IRCRA reporting [5] it reached (mean ± SD) 24.8 ± ± 5.4. As pulling up on a fingerboard, including loaded pull-ups, was previously regularly performed by the participants as a regular part of their training program, no familiarization session was included in the present study. Before testing, the participants were instructed to perform a warm-up consisting of a series of climbing circuits on a bouldering wall followed by a series of five dynamic pull-ups on a fingerboard and on portable holds.

Instruments

The Gyko inertial sensor system (Microgate, Bolzano, Italy) was used to register velocity (in m/s), force (in N) and power (in W) of pull-ups, as well as establish 1RM (in kg) pull-up.

This device was previously used in other studies, in which its reliability and validity were confirmed [6, 7, 13]. The device contains a three-dimensional accelerometer (range: ±2 G), a gyroscope (250°/s-25,000°/s) and a magnetometer (range: ±4800 μT). It provides recordings at a sampling frequency of 1 kHz. Participants had the Gyko sensor (dimensions: 53 × 51 × 23 mm, mass: 46 g) attached at the level of the body centre of mass on the back using an elastic belt provided by the manufacturer. During measurements the signals were transferred via a Bluetooth 4.0 to the Lenovo PC with the RePower software installed, following the criteria described by the manufacturer.

The pull-up tests were performed on a Witchboard Hard fingerboard (Witchholds, PL) using two 4 cm deep jugs, and Rock Rings portable holds (Metolius, USA), as presented in Figure 1. In both cases pull-ups were performed on the biggest jugs with similar dimensions.

Figure 1. Portable holds (left), fingerboard (upper, right), and Gyko inertial sensor (bottom, right). The ovals mark the holds on which the subjects performed pull-ups

The procedure of the test
After a warm-up the participants performed a series of dynamic pull-ups on a fingerboard or on portable holds, consisting of three repetitions with the aim to complete them as quickly as possible. After 1 minute of rest, those who performed the first series on the fingerboard pulled up on the portable holds and vice versa. A four-minute rest period was followed by 1RM pull-up trials, separated by 10 minutes of rest. Each trial consisted of three series of pull-ups with increasing load, from which the RePower software made a 1RM calculation. As practically all climbers knew the load, at which they could perform 5-6RM, the first series was started with this load. The intervals between the series in the trials were 2 minutes. To maintain maximum kinematic similarity between the pull-ups performed on the Rock Rings and the fingerboard, the subjects were instructed to keep their palms facing the dorsal surface towards the face during the former. To eliminate the potential interfering effect of the exercise order, half of the subjects started the trials with the fingerboard and the other half with the portable holds.

Statistical analysis
Descriptive statistics (means, standard deviations and 95% confidence intervals for mean values) were used to describe the data. The force, velocity and power values are presented as the maximum values of these parameters in a series of three dynamic pull-ups and the average of the three pull-ups comprising the series. Assumptions of normality and homogeneity of variance were tested with the Shapiro–Wilk and Levene's tests, respectively. Repeated measures ANOVA with the Bonferroni post hoc test was used to assess the differences between conditions. As a measure of effect size between both conditions eta-squared (η^2) was used with the following interpretation: 0.01 = small; 0.06 = medium; and 0.14 = large [9]. Statistical significance was accepted at $p < 0.05$. All analyses were conducted using the Statistica 13.3 software program (TIBCO Software Inc., Palo Alto, CA, USA).

Results

Descriptive statistics are presented in Table 1. Analysis of variance revealed the statistical significance of the device type (portable vs. fingerboard) in the case of 1RM pull up, with the fingerboard enabling greater 1RM values compared to portable holds $F_{(1.15)} = 36.6$, $p < 0.001$, $\eta^2 = 0.71$. On average, the value of 1RM was 8.5% higher (2.7 kg) for fingerboard pull-ups than for portable holds, with the effect size measure suggesting that the difference is of practical significance. When

Table 1. Values of force [N], power [W], velocity [m/s] and 1RM [kg] of pull-ups performed by climbers on the fingerboard and portable holds

	Fingerboard		Portable holds		Fingerboard/Portable holds comparison
	M (SD)	CI ± 95%	M (SD)	CI ± 95%	
Max force [N]	1762.3 (862.6)	1302.7-2222.0	1768.8 (890.9)	1294.1-2243.5	$F_{(1.15)} = 0.0$, $p = 0.962$
Max velocity [m/s]	1.43 (0.38)	1.23-1.63	1.41 (0.48)	1.15-1.66	$F_{(1.15)} = 0.3$, $p = 0.597$
Max power [W]	1775.7 (1103.9)	1187.5-2364.0	1837.7 (1351.3)	1117.6-2557.7	$F_{(1.15)} = 0.2$, $p = 0.681$
Mean force [N]	1492.3 (636.2)	1153.3-1831.3	1519.6 (704.9)	1144.0-1895.2	$F_{(1.15)} = 0.1$, $p = 0.811$
Mean velocity [m/s]	1.36 (0.40)	1.15-1.57	1.28 (0.40)	1.06-1.49	$F_{(1.15)} = 3.7$, $p = 0.075$, $\eta^2 = 0.20$
Mean power [W]	1531.4 (885.6)	1059.5-2003.3	1336.3 (851.6)	882.5-1790.0	$F_{(1.15)} = 8.7$, $p = 0.010$, $\eta^2 = 0.37$
1RM [kg]	34.3 (12.2)	27.8-40.8	31.6 (11.8)	25.3-37.9	$F_{(1.15)} = 36.6$, $p < 0.001$, $\eta^2 = 0.71$

comparing maximum values obtained at the dynamic pull-ups on a fingerboard and on portable holds, no significant differences were observed in force (p = 0.962), velocity (p = 0.597) or power (p = 0.681). However, as shown by the analysis of variance, there was a tendency towards greater mean velocity across three pull-ups performed on a fingerboard compared to portable holds and significantly greater power output of pull-ups performed on the former.

Discussion

The main purpose of this study was to compare velocity, power, force and 1RM values during pull-ups performed on both types of devices. Despite their similarity in terms of hand placement (type of grip, its depth, etc.), they offer different exercise conditions, being in a sense the equivalent of exercises performed on a stable and unstable surface [14]. While a number of studies were conducted to compare the effects of exercising on stable vs. unstable surfaces [2, 3, 12], most of them focused on activities performed in supported positions. Their results have limited applicability to exercises performed in overhanging positions, which predominate in climbers' training. In this study it was hypothesised that training on the fingerboard would promote greater 1RM values, while portable holds would promote greater velocity of pull-ups and higher power output. The recorded results confirmed this hypothesis, with the subjects obtaining 1RM values on the fingerboard on average about 8.5% higher than during pull-ups on the portable holds. What is noteworthy, virtually every subject achieved a higher score, with individual differences ranging from 1 to 6 kg. Nevertheless, the other variables (velocity, power and force) were similar during pull-ups on portable holds and pull-ups performed on a fingerboard. Only in the case of power, the difference between both conditions was statistically significant, although small considering the effect size.

The information gained from the research can provide practical guidance for coaches and athletes involved in climbing. Any sports training session aims to maximise fitness and the right choice of exercises and equipment should make this possible. Since a wide variety of equipment for performing pull-ups is currently available for climbers, they are faced with the dilemma which equipment to choose to serve the assumed training goals best or, conversely, whether they are equivalent to each other in achieving specific goals. Our study suggests that the differences between fingerboards and portable holds are insignificant or small in most of the movement parameters assessed, except for the 1RM value, which was significantly greater on the fingerboard. The higher values of the external load, with which the subjects could perform the maximum pull-up repetition suggest that this apparatus should be the preferred choice in exercises aimed at developing maximal strength in pull-ups.

There are a few limitations of this study that need to be considered when interpreting its results. Firstly, is connected with the relatively small number of subjects, which limits data analysis, since the participants could not be further divided into subgroups of different strength and climbing levels. Secondly, climbers were asked to keep a similar position of the hands on the holds while performing pull-ups, which in the case of portable holds, where they spontaneously undergo a slight rotation, required special attention from the participants. This fact may have had some influence on the way they performed their pull-ups. Rock Rings are only one of many available types of portable holds, thus other types of such devices should also be investigated to see if the relationships found are more universal.

Conclusions

On the basis of this study it may be assumed that fingerboards (fixed in a stable way) may be relevant in developing maximal strength in pull-ups. Further research in this area, especially experimental, is needed to confirm such a conclusion.

Conflict of Interests

The authors declare no conflict of interest.

References

1. Behm DG, Anderson KG, Curnew RS. Muscle force and activation under stable and unstable conditions. J Str Cond Res. 2002;16:416-422. doi:10.1519/JSC.0b013e3181f0a8b9.
2. Behm DG, Muehlbaue T, Kibele A, Granacher U. Effects of strength training using unstable surfaces on strength, power and balance performance across the lifespan: a systematic review and meta-analysis. Sports Med. 2015; 45:1645-1669. doi:10.1007/s40279-015-0384-x.
3. Chulvi-Medrano I, Martínez-Ballester E, Masiá-Tortosa L. Comparison of the effects of an eight week push up program using stable versus unstable surfaces. Int J Sports Phys Ther. 2012;6:586-594.
4. Dickie JA, Faulkner JA, Barnes MJ, Lark SD. Electromyographic analysis of muscle activation during pull-up variations. J Electromyogr Kinesiol. 2017;32:30--36. doi:10.1016/j.jelekin.2016.11.004.
5. Draper N, Canalejo JC, Fryer S, Dickson T, Winter D, Ellis G, et al. Reporting climbing grades and grouping

categories for rock climbing. Isokinet Exerc Sci. 2011; 19(4):273-280. doi:10.3233/ies-2011-0424.
6. Forza J, Edmundson CJ. Comparison between Gyko inertial sensor and Chronojump contact mat for the assessment of squat jump, countermovement jump and Abalakov jump in amateur male volleyball players, amateur male rugby players and in high school students. J Multidiscip Eng Sci Technol. 2019;6(4):9982-9988.
7. Hamersma DT, Hofste A, Rijken NHM, Roe of Rohé M, Oosterveld FGJ, Soer R. Reliability and validity of the Microgate Gyko for measuring range of motion of the low back. Musculoskelet Sci Pract. 2020;45:102091.
8. Koshida S, Urabe Y, Miyashita K, Iwai K, Kagimori A. Muscular outputs during dynamic bench press under stable versus unstable conditions. J Strength Cond Res. 2008;22:1584-1588. doi:10.1519/JSC.0b013e31817b03a1.
9. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for *t*-tests and ANOVAs. Front Psychol. 2013;4(863):1-12. doi:10.3389/fpsyg.2013.00863.
10. McBride JM, Cormie P, Deane R. Isometric squat force output and muscle activity in stable and unstable conditions. J Strength Cond Res. 2006;20:915-918. doi:10.1519/R-19305.1.
11. Michael MK, Witard OC, Joubert L. Physiological demands and nutritional considerations for Olympic-style competitive rock climbing. Cogent Med. 2019;6: 1667199. doi:10.1080/2331205X.2019.1667199.
12. Sanchez-Sanchez J, Raya-Gonzalez J, Ramirez-Campill R, Chaabene H, Petisco C, Nakamura FY. The increased effectiveness of resistance training on unstable vs. stable surfaces on selected measures of physical performance in young male soccer players. J Strength Cond Res. 2020 May 13. doi:10.1519/JSC.0000000000003590.
13. Santospagnuolo A, Bruno AA, Pagnoni A, Martello F, Santoboni F, Perroni F, et al. Validity and reliability of the GYKO inertial sensor system for the assessment of the elbow range of motion. J Sports Med Phys Fitness. 2019;59(9):1466-1471. doi:10.23736/S0022-4707.19.09331-9.
14. Snarr RL, Hallmark AV, Casey JC, Esco MR. Electromyographical comparison of a traditional, suspension device, and towel pull-up. J Hum Kinet. 2017;58:5-13. doi:10.1515/hukin-2017-0068.