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## **The Relationship Between Rock Climbing and Total Body Strength and Endurance**

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### **INTRODUCTION**

Rock climbing is a physically and mentally demanding sport and is growing in popularity of its recreational form. There are various types of rock climbing including bouldering, free climbing, top rope climbing, and alpine climbing to name a few. However, the most popular subdivision of rock climbing to date is indoor top rope climbing (Draper, Jones, Fryer, Hodgson, & Blackwell, 2014). Top rope climbing involves the climber being harnessed and connected to a rope that runs from the climber's harness to a pulley-clip located at the top of the wall then through the harness of the belayer, who remains at ground level. This type of climbing decreases the risk of injury to the climber since the belayer has more control over the fall distance. Top rope climbing is tailored to novice and experienced climbers alike and, when conducted indoors, it allows participants to climb at any time, regardless of outdoor conditions.

There are many factors that can influence a person's ability to climb, including both psychological and physical factors. Rock climbing ability can be influenced by body mass as well as upper and lower body strength and endurance. Most climbers have a high strength to mass ratio with a smaller physique which allows them to climb more efficiently (Giles, Rhodes, & Taunton, 2006). A smaller body mass can give climbers a climbing advantage because body mass is the main resistive force on the body during a climb (Ozimek, Staszkievicz, Rokowski, & Stanula, 2016). Previous research has identified an association between upper body strength and endurance and improvements in climbing performances. The movements performed during rock climbing provide a large amount of force to the upper body. While climbing, there are instances where the hands and fingers are supporting total body weight (Stankovic, Joksimovic, & Aleksandrovic, 2011). Total body support is necessary for rock wall climbing because the lower body provides the strength

to propel the individual through the course, whereas, the upper body will provide the strength to move in different directions throughout the climb.

Past studies have used various strength and endurance tests to assess muscular strength and endurance, such as grip strength, finger strength, and flexed arm hang tests (Grant, Hasler, Davies, Aitchison, Wilson, & Whittaker, 2001). Grip strength and finger strength have been used in multiple studies as predictors of an individual's climbing performance. Gurer and Yildiz (2015) claim that insufficient grip strength "is generally one of the main reasons for [failing] a climb route." It has been shown that the right hand has a greater handgrip strength when compared to the left hand, and therefore may play a more dominate role in the climbing process (Gurer, & Yildiz, 2015).

While upper body strength and endurance can indicate performance, the lower body also plays a vital role in climbing ability. During a vertical rock wall climb, more of the body mass is supported by the legs (Watts et al., 2008). This especially pertains when the body is driven upward during a climb because the lower limbs do not fatigue as quickly as their upper counterparts (Michailov, 2014). Lower body strength and endurance are frequently tested using leg press exercises (Escamilla et al., 2001). The leg press is a common multi-joint exercise utilized to enhance performance in sports, as it recruits large and powerful muscles. Rock climbing performance requires efforts of the entire body, so assessing strength and endurance of the lower body may provide another indicator for climbing performance.

Past research has assessed the impact that muscular strength and endurance can have on climbing ability for elite and trained climbers. There remains a need for further research on the impact that muscular strength and endurance has on the general population. Rock wall climbing has become a recent trend for all ages and experience levels. Identifying the importance of upper and lower body strength and endurance can potentially set interested participants at ease by showing them that they do not have to have years of experience to excel at climbing. Instead, simply practicing rock climbing has been shown to be an effective technique for improving performance (Furlonger, 2017). Previous research has found that successful climbing is related to total body muscular strength and endurance, so individuals of all skill levels should have a faster climb if they already possess those traits. The purpose of our study was to assess whether muscular

strength and endurance ability can lead to a faster rock wall climb. Therefore, we hypothesized that if an individual performs better on their muscular strength and endurance tests, then they will have a shorter time to completion for their climb.

## **METHODS**

### Participants

In order to learn more about the muscular factors that play a role in rock climbing, this study aims to investigate the relationship of muscular strength and endurance on rock climbing ability. Georgia College students, ranging 19-25 years of age, were recruited by posting flyers in approved locations around campus, posting an electronic flyer on the school's Exercise Science Club Facebook page, and through word of mouth by the investigators. In order to meet eligibility requirements, participants were deemed ready for physical activity by answering "no" to the initial seven screening questions on the Physical Activity Readiness-Questionnaire+ (PARQ-+). The PAR-Q+ served to identify any major signs, symptoms, and/or conditions that would contraindicate exercise and exclude the individual from safely participating in this research investigation. Prior rock climbing experience was not required for participation.

### Procedures

Individuals interested in participation in this study contacted investigators via email and were sent a PAR-Q+ and an informed consent document. The potential participant electronically completed the PAR-Q+, and sent it back to investigators for eligibility review. The investigators responded to either inform the individual that they were not eligible for participation or to set up an initial data collection appointment time.

Data collection occurred over the course of two sessions, which were separated by at least 48 hours but less than one week, so that the data collection process in the first session did not affect that of the second. Participants were asked to arrive to the testing location on both occasions at the specified date and time, having done the following: refrained from smoking, eating, and drinking anything besides water for two hours prior to their appointment, having refrained from strenuous exercise for 24 hours before their

appointment, arriving dressed in clothes that were not ill-fitting, and wearing athletic shoes. It was recommended to wear shorts with spandex, or bottoms that came at least to mid-thigh during the rock climbing session for full coverage throughout the climb.

### Initial Data Collection

When participants arrived to the testing location, they read and signed two informed consent documents and were asked to complete a questionnaire to provide a greater understanding of the participant's mentality on rock climbing. One informed consent document was kept by the investigator and the other was given to the participant for their records. Prior to the start of data collection, investigators answered any questions and concerns the participant had about the study. A three-minute warm up on a rowing ergometer machine was conducted before the participant's grip strength was measured using a Smedley handgrip dynamometer, which measures the force exerted in kilograms (kg). The device was fitted to the participant's hand and a maximal grip was performed with the participant's arm abducted and elbow in full extension from their body so that the dynamometer was approximately thigh height. Three trials for each hand with pauses of 60 seconds were administered. The highest measure for each hand was used for analysis.

The participant then performed a 10-repetition maximum (10-RM) leg press, which assessed lower body endurance. This assessment was performed on a leg press machine that sat upright to more closely mimic the biomechanical movements performed during a climb. The participant was fitted to the machine so that they were comfortably positioned with their legs at 90 degrees and their feet shoulder-width apart. The 10-RM will be determined within four trials with 3-5 minutes between trials. The initial weight will be selected based on the subject's perceived capacity. Resistance will be progressively increased until the subject cannot complete the 10 repetitions, and all repetitions will be performed at the same speed of movement and range of motion for consistency between trials. The final weight lifted successfully for 10 repetitions will be recorded.

Following the leg press, a flexed-arm hang test was conducted to assess upper body endurance, an important component of rock climbing due to the body being pulled upwards during a climb. The participant was asked to use an underhand grip on a bar, and pull themselves up so that their chin was above the bar but not touching it. This position

was held for as long as possible and the test was terminated once the position was broken. An investigator monitored and recorded the time of the hang (Reinman & Manske, 2009). The last test performed was a plank test, which was used to assess core strength and endurance. The participant held the plank position with their forearms and toes in contact with the ground and their back flat until the test was terminated when the participant could no longer maintain the proper positioning (Reinman & Manske, 2009).

After all tests were completed, the investigator asked the participant to perform static stretches lead by the investigators for five minutes to decrease the possibility of soreness. During this time, investigators reviewed possible side effects participants may feel due to the fitness tests, answered any questions, and set up a follow up appointment for the second day of data collection at least 48 hours after but no longer than one week following the initial visit. Before the participant left, the investigator gave them a sheet of paper that contained tips for the day of their rock climb.

#### Follow-Up Data Collection

Participants were asked to sign two mandated waivers from the rock climbing wall facility in order to climb the rock wall before data collection began on the second day. After the waiver was signed, a three-minute rowing ergometer warm up was conducted to decrease the possibility of soreness and/or injury. The investigator then explained to the participant how the climbing test would be carried out. Investigators showed the participant the specified stopping point that the feet of the individual had to surpass for the climb to be considered “complete,” and explained that the climb should be done as quickly as possible. A belay-trained individual employed by the climbing facility fitted the individuals with shoes, harnessed the individual, and reviewed safety information and commands. The participants were instructed that they could stop the climb at any time and that the belayer reserved the right to tell the participant to slow down if they could not keep up with the speed of the climb.

After all instructions were given and all questions were answered, the investigators signaled for the participant to start climbing the wall as quickly as possible and started a stopwatch. The test was terminated when the climb was completed or if the individual requested to stop. The participant, belayed back to the ground, was unharnessed by a

trained Wellness & Recreation Center staff member and performed a cool down consisting of two sets of 30-second holds of the following static stretches: hamstring stretch, downward-facing dog stretch, and a deep shoulder stretch. The investigator questioned the participant on any symptoms of fatigue or overexertion and informed them of any possible side effects of climbing. The participant was free to leave once investigators were certain that no acute adverse effects were present.

## STATISTICAL ANALYSIS

Descriptive statistics ( $M \pm SD$ ) were calculated for all variables, including handgrip strength, 10-RM leg press, flexed-arm hang time, plank time, and climb time. Data were analyzed using Pearson Product Moment Correlation to detect relationships between continuous variables. An independent t-test was utilized to look at differences between males and females. For our analyses, the alpha level was set to  $p < 0.05$ . Data analyses were conducted using Statistical Package for the Social Sciences (SPSS) version 22.

## RESULTS

A total of 22 students volunteered to participate in the study ( $n=22$ ): 11 males and 11 females. Of the participants, 23% of the participants were novice rock climbers while 77% had at least some previous exposure to rock climbing. Participants were 19-25 years of age and only excluded if they failed to be cleared for physical activity by the PAR-Q+. All 22 participants that volunteered for the study met eligibility requirements and were included in all data analyses.

A Pearson's Test of Correlations showed a significant, moderately negative correlation between right-hand grip and rock climbing time ( $r=-0.47, p=0.027$ ), left-hand grip and rock climbing time ( $r=-0.49, p=0.022$ ), total hand grip and rock climbing time ( $r=-0.49, p=0.019$ ) (**Figure 1**), 10 repetition maximum (RM) leg press and rock climbing time ( $r=-0.46, p=0.033$ ) (**Figure 2**), and flexed-arm hang and rock climbing time ( $r=-0.51, p=0.015$ ) (**Figure 3**). Handgrip strength was measured in kilograms (kg), 10RM leg press ability was measured in pounds, and flexed-arm hang time and rock climb time were measured in seconds.

An independent t-test found that the rock climbing time in seconds of those with rock-climbing experience ( $\pm$  SD) did not show a significant difference when compared to those with no rock climbing experience ( $\pm$  SD), 37.00 ( $\pm$ 17.30) and 45.20 ( $\pm$ 36.68). A separate independent t-test found that there was a significant difference for participants that were afraid of heights compared to their unafraid counterparts, results reported respectively, when it came to exercise frequency in days per week ( $\pm$  SD), 2 ( $\pm$  1) and 4 ( $\pm$  2), flexed-arm hang in seconds ( $\pm$  SD), 10.75 ( $\pm$  9.56) and 22.57 ( $\pm$  13.92), and rock climbing time in seconds ( $\pm$  SD), 52.25 ( $\pm$  29.33) and 31.21 ( $\pm$  12.87).

Finally, an independent t-test looking at differences between males and females, reported respectively, showed that males performed significantly better at right-hand grip in kilograms ( $\pm$  SD), 47.2 ( $\pm$  8.5) and 28.5 ( $\pm$  6.1), left-hand grip in kilograms ( $\pm$  SD), 45.4 ( $\pm$  7.8) and 24.8 ( $\pm$  6.0), total hand grip in kilograms ( $\pm$  SD), 92.2 ( $\pm$  15.0) and 53.3 ( $\pm$  11.9), 10RM leg press in pounds ( $\pm$  SD), 427 ( $\pm$  194) and 195 ( $\pm$  46), flexed-arm hang in seconds ( $\pm$  SD), 25.82 ( $\pm$  14.31) and 10.73 ( $\pm$  7.54), plank in seconds ( $\pm$  SD), 112.18 ( $\pm$  53.75) and 71.64 ( $\pm$  29.07), and rock climbing time in seconds ( $\pm$  SD) 26.64 ( $\pm$  7.63) and 51.09 ( $\pm$  25.61). The difference in rock climbing times for male and females is shown in **Figure 4**. The only variable that was not significantly different between males and females was exercise frequency in days ( $\pm$  SD), 4 ( $\pm$  2) and 3 ( $\pm$  2) respectively.

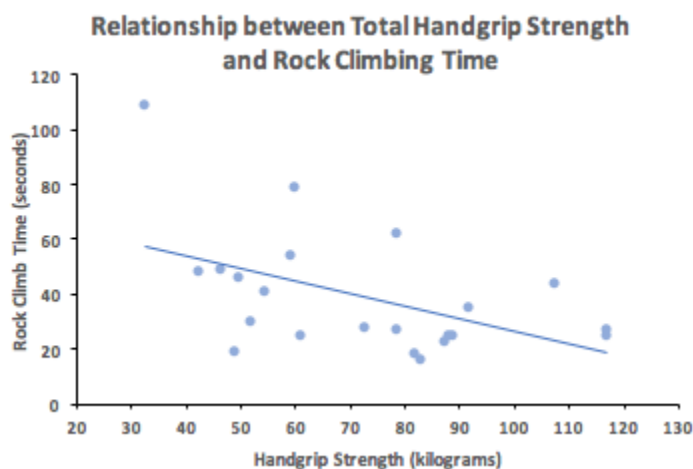


Figure 1: Relationship between Total Handgrip Strength\* (kilograms) and Rock Climbing Time (seconds) (n=22)

\*Total and grip strength was determined by the addition of right and left-hand grip scores



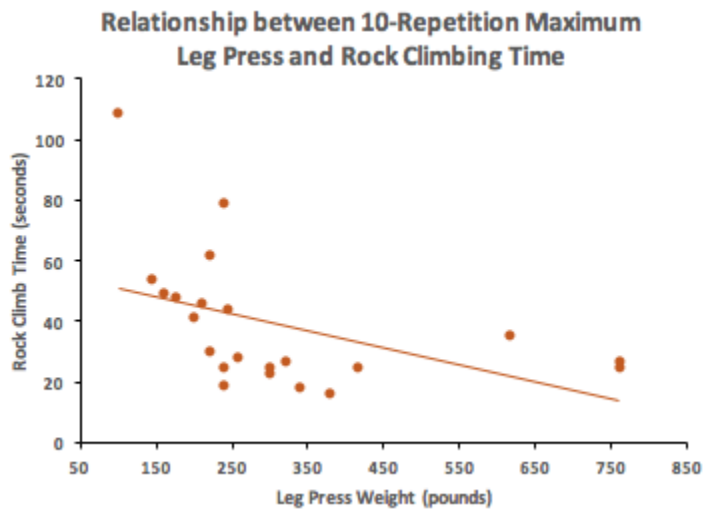


Figure 2: Relationship between 10-Repetition Maximum Leg Press (pounds) and Rock Climbing Time (seconds) (n=22)

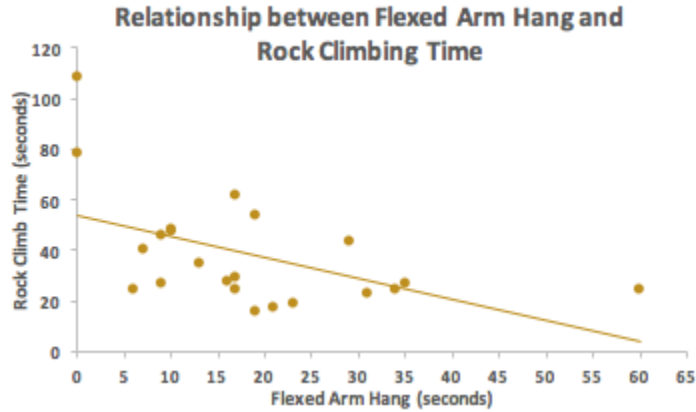


Figure 3: Relationship between Flexed Arm Hang (seconds) and Rock Climbing Time (seconds) (n=22)

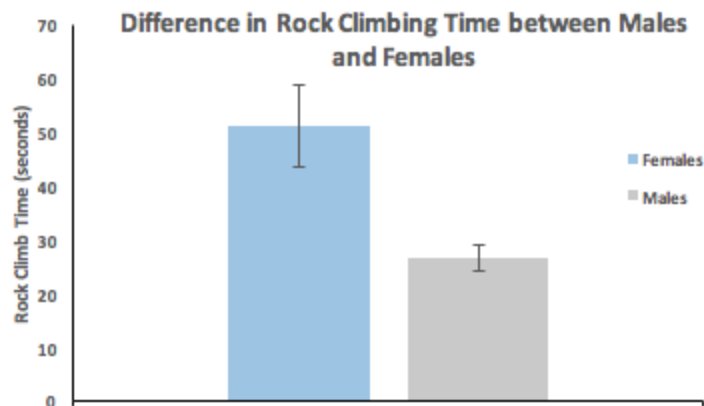


Figure 4: Difference in Rock Climbing Time (seconds) between Males (n=11) and Females (n=11)\*  
\*Data are presented as M ( $\pm$ SD).

## DISCUSSION

The purpose of this study was to determine if muscular strength and endurance fitness rankings had an effect on a timed rock climb. It was hypothesized that the individuals who performed well on their muscular strength and endurance tests would complete their rock climb faster. Data collection and further analysis support this notion and the null hypothesis was rejected. Thus, it was concluded that superior fitness rankings were associated with a faster rock climb.

After analyzing the results of the study, the researchers concluded that there was a moderate negative correlation between total handgrip strength, flexed-arm hang, and the 10 repetition maximum leg press, in comparison to rock climbing time. This negative correlation is important because it indicates that the individuals who performed better on these fitness tests were able to complete the climb in a shorter time period.

While it was shown that stronger performance on fitness tests was related to improved rock climb time for the overall sample, differences were also noticed between genders in relation to fitness test and rock climbing abilities. There was a significant difference between the rock climbing times recorded for male and female participants. This can be related to fitness rankings earned by males and females. On average, males had higher total handgrip strength compared to their female counterparts. This is potentially

due to the increased relative strength that males have compared to females. Males have proportionally more lean body mass and are able to rely more on their upper body strength during a climb. According to Gure and Yildiz (2015) male climbers consistently rely on their hand muscles while rock climbing. Increasing the muscular ability of the hands allows for one to rely more on the hands during a climb since more stress can be placed on them, resulting in a shorter overall rock climbing time.

While grip strength is an indicator of upper body strength, this study also looked at one's ability to complete a flexed-arm hang due to the ability of the test to measure similar biomechanical stressors. It was found that the flexed-arm hang test had the highest correlation to rock climbing ability, compared to all of the fitness tests that were measured in this study. Individuals who were able to hold their flexed-arm hang for longer were able to complete their rock climb faster than those who were not able to complete the test at all or hold the position for as long. Past and present findings can lead one to conclude that upper body strength is an important determinant of rock climbing ability.

In addition, the 10 repetition maximum assessment of lower body strength was an indicator for performance on the timed rock climb. Individuals who were able to press more weight were also able to climb the rock wall more quickly. This could be related to a reliance on the individual's legs to propel them upwards during the timed climb. The increased use of the lower extremities during longer rock wall climbs can delay exhaustion of the upper limbs. By using the lower body in combination with the upper body, one can more efficiently transfer and utilize energy stores in different areas of the body. Individuals should not exclusively rely on the upper or lower body, but rather incorporate total body movements to improve overall rock climbing skill.

The results from the data collected from this study can be applied to both novice and elite rock climbers. While the act of rock climbing can lead to refined climbing skills and decreased climb times, it was shown that novice climbers can be equally successful if they possessed an increased level of muscular strength and endurance. This knowledge can lead to alterations in training programs for those interested in improving their rock climbing speed. Instead of following the 'practice makes perfect' mentality, interested individuals may benefit from focusing on increasing their total body strength and endurance capabilities.

Although this research was carefully conducted, several limitations presented themselves throughout the study. Since the 10-repetition maximum leg press was used to collect data, it could not be compared to a normative data table since the participant's body weight was not measured nor recorded. Future studies could collect anthropometric and demographic information, such as body weight and age, from participants in order to be able to further evaluate fitness rankings in relation to the specific individual's build and background.

While completing the questionnaire, participants did not always provide clear, concise answers about their rock climbing experience. In order to have a better structured questionnaire, future studies should limit the use of free response answers and rather lean towards a "yes/no" or a scale format. In relation to questionnaires, it could be potentially beneficial to have a post-rock climb evaluation form in which participants can describe their thoughts and feelings after performing the climb in order to gain insight into their experience.

The use of medication was not fully investigated. Participants were asked if they were currently on any medications; however, they were not asked to go into detail as to what those medications were, the frequency of ingestion, nor the dose prescribed. Certain medications, like oral contraceptives (Suh, Casazza, Horning, Miller, & Brooks, 2003), can alter exercise ability and capacity, therefore possibly affecting the results in some way. However, the scope of these effects were not examined in the present study and could be inspected further in future studies.

The climbing distance that was selected for this particular study could have been longer and more challenging in order to test the participant's muscular endurance and strength more specifically. There was also no specific route that climbers were asked to follow, so future studies should specify a normalized climbing path that has a specific level of difficulty to it for the climbers to follow. This will create independent scores that can be more accurately obtained and compared. Future studies should ensure that these specific problems are addressed in order to obtain the most valuable results possible.

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