Assistive Clipping Device for Lead Climbers with Limited Dexterity in One Hand

Isadora Smith, Colin Wills, and Diego Wong
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Abstract

Paraclimbing is a category of rock climbing for athletes with a disability that prevents any normative function. In this study, we focused on climbers with the AU2 classification and found that clipping during lead climbing is a challenge. It is a task that requires fine manipulation and poses the highest risk of falling. Currently, there are no devices aimed to assist climbers with limited to no hand dexterity. Thus, we designed an assistive clipping device for AU2 climbers aimed to limit the risk of falling while lead climbing. Our passive device is worn on the arm and uses hooks to stabilize carabiners and push the rope through the gate while clipping. With our proposed device, we expect a decrease in the average speed of clipping and the anxiety levels of climbers while lead climbing. Increased efficiency when clipping leads to a decrease in the risk of falling, which widens the opportunities for AU2 climbers. Our novel prototype attempts to fill the wide gap in assistive rock climbing devices, however, there is still much to be explored in this field.

I. Introduction

With the significant growth the sport of rock climbing has seen in the last 20 years, it comes as no surprise that paraclimbing has undergone a similar, if not more dramatic growth in recent years [1]. Supported by organizations like the ParaCliffHangers, who host community climbing sessions at gyms and outdoor destinations across the United States, paraclimbing encompasses a broad category of rock climbing that includes any climber with a disability that prevents some level of normative function [2]. While paraclimbing extends far beyond the competitive sphere, the classifications used by competitive organizations like the International Federation of Sport Climbing (IFSC) and USA Climbing (USAC) are useful to differentiate the variety of capabilities and ability levels paraclimbers possess. This investigation focuses on the AU2 competitive paraclimbing classification, which describes any climber with use of one full arm and one stump to climb [3]. Climbers in this category have full lower body ability and full normative capacity in one arm but are limited by their dexterous capacity as a result of a missing hand. Further, this proposal explores a device intended to reduce risk and increase versatility for AU2 climbers during a technically demanding high-risk stage of climbing.

A. Background

Rock climbing as a sport is focused on climbing up a wall or rock with the use of only one's limbs[4]. External equipment is generally used solely for safety purposes to reduce the risk of lasting injury or death. As a result, equipment is designed to be lightweight, minimizing its impact on climbing performance. However, there are no assistive devices or equipment for climbers who have limited or no hand dexterity. There is a significant gap in this research, which limits opportunities for paraclimbers seeking to learn more about their disability, particularly in the case of lead climbing.

Lead climbing is a discipline of rock climbing wherein the climber ascends a wall with a rope, clipping into anchor points called quickdraws as they go. This means that the climber must move between protection points, risking a fall that is twice the relative distance from the last anchor point [5]. The moment of highest risk on a lead climb is when the climber has reached a quickdraw but is not yet clipped into the protection point, as this is the furthest a climber reaches above their last protection point.

The action of clipping involves a climber stabilizing on the wall before removing one hand, grasping the rope from its attachment point on the harness, and pulling the rope up to force it through a hanging quickdraw [5]. This is a technical moment physically and mentally, as it is often difficult to remove one hand from the wall while fatigued, and the climber is usually fully aware of the risk falling poses. Further, forcing the rope through a gate requires a precise grasp to stabilize the gate and fine finger movements to force the rope through while stabilizing the gate [6]. For an AU2 climber, clipping is made far more difficult by the fact that the climber has no way to fully stabilize the draw, as the functional hand must be occupied maintaining a contact point with the rock. An AU2 climber also cannot delicately manipulate the rope as needed to clip the way a normative climber generally would [7]. Existing research suggests that decreased confidence in climbing and clipping ability results in increased anxiety and physical exertion while climbing, hence increasing clipping confidence may reduce the psychological and physiological demands of lead climbing [8][9][10].

There are currently no assistive devices that address AU2 climbers, but clipping aids called stick clips are commonly used to clip the first draw of a route from the ground to ensure climber safety. However, these devices are not intended to be used while climbing and generally rely on the use of both hands, thus they may be observed for design inspiration but are not a sturdy basis from which to build an on-the-wall clipping aid. If climbers with limited to no hand dexterity use an assistive device to clip a rope while lead climbing, then the risks associated with falling while clipping will decrease. Our project will focus on filling this gap and make lead climbing more accessible to paraclimbers.

B. *Overview*

The rest of this proposal is divided into Sections II, III, IV, and V. Section II will analyze an interview conducted with a competitive AU2 paraclimber and present the outcomes of data collection. Section III will explain our proposed device and the testing methods we will conduct to test the efficiency and effectiveness of the device. Section IV will discuss the novelty of the device from a research and engineering perspective and the need for further research in this field. Lastly, section V will discuss the impact the device has on the accessibility of climbing and its implications for future generations.

II. Interview Case Study

Prompt/Theme	**Interview statement**	**Interpreted need**
Lead Climbing	"Clipping is probably the number one issue... you want to be able to clip as smoothly and as cleanly as possible... that's where you're more injury prone."	Values reduced injury risk while clipping on a lead climb.
	"When I clip for lead climbing, I rely on gravity to open the gate. But it is difficult and if there are bigger clips, then it's easier to stick my arm in."	Needs versatile clipping solution that does not rely on clip size, position, or hand dexterity.
Assistive Technology	"I tried a passive arm when I was little and it was miserable... It's still heavy as hell... I guess I've always been 100% functional without needing one, so I never felt the need to."	Values a balance of comfort, functionality, and ease of use.

TABLE I
KEY POINTS COLLECTED FROM THE INTERVIEW.

Shown above in Table I is the summary of data collected during a need-finding interview. A nationally-ranked competitive AU2 lead climber was interviewed to determine the challenges they face and the adaptations they've made climbing with a stump on one arm. Zoom was used to record video and audio of the interview so that a transcript could be generated from the recordings. The interviewee seemed relatively comfortable speaking on their experience as a paraclimber and living without one hand, particularly how they have always perceived themself as a fully functional individual. Unfortunately, the major issues the climber identified in their climbing surrounded difficulties using some hold types. The use of assistive devices to grab holds or physically aid a climber's ascent is generally frowned upon within the community since it diminishes a climber's achievement, so this is not an avenue through which a useful solution would be produced.

Instead, the interviewee identified a consistent struggle while clipping during lead climbing. The extra effort required to clip each draw cause greater fall-related anxiety and require higher levels of exertion, while the restrictiveness of the adapted motion severely limit the clipping positions available while the athlete is on the wall. This makes climbs with distant clips impossible and significantly limits what climbs they can attempt. Not only does the lengthened time on the wall increase the likelihood of a dangerous fall toward the top of a route, but anxiety also makes it more difficult to execute each move and further increases the physical and mental toll of a climb. Thus reducing the burden of clipping could improve their performance on the wall and increase the range of climbs accessible to them.

The interviewee also identified negative past experiences with assistive devices and prosthetics, indicating that comfort and immediate practical usability are priorities and must be satisfied for them to consider using an assistive device in the future. Finally, the interviewee explained how they use a majority of the surface on the underside of their arm to grasp and maneuver around holds, indicating that this useful area must not be obstructed while they are climbing. A non-invasive clipping assistive device was selected as the subject of investigation.

III. Proposed Device & Test Methods

A. Proposed Device

Our group's proposed device is an assistive clipping device for lead climbers with limited dexterity. It is a passive device that is worn on the end of the arm for increased range of motion. It uses a soft mount securely fastened to the arm to limit interference with climbing movements. The mount is fastened to the arm via an adjustable Velcro strap to further reduce the impedance of the usable forearm space. The profile of the device is also designed not to interfere with the wall, climbing holds, or the act of climbing. The device has a hook that rests on the lower carabiner of the quickdraw to be clipped. This hook's purpose is to stabilize the carabiner by applying a downward force. A stabilized carabiner is easier to manipulate and force a rope through the gate. Above this hook is a notch that the rope fits into. This notch will hold the rope in place until it is placed into the carabiner. Once the climber is ready to clip, they will set the rope into the notch, then rest the hook onto the carabiner. The climber uses a twisting action to push the rope through the gate and into the carabiner. The rope will fall out of the notch of the device due to gravity and the twisting motion. Then the climber will continue climbing until they have the clip the rope again. Figure 1 shows the device and it's features and fig 2 shows the progression of normative clipping action. Figure 3 shows the progression of clipping with our proposed device when it is mounted on the forearm. A 3D CAD model is shown in the appendix for further visual detail in figure 5.

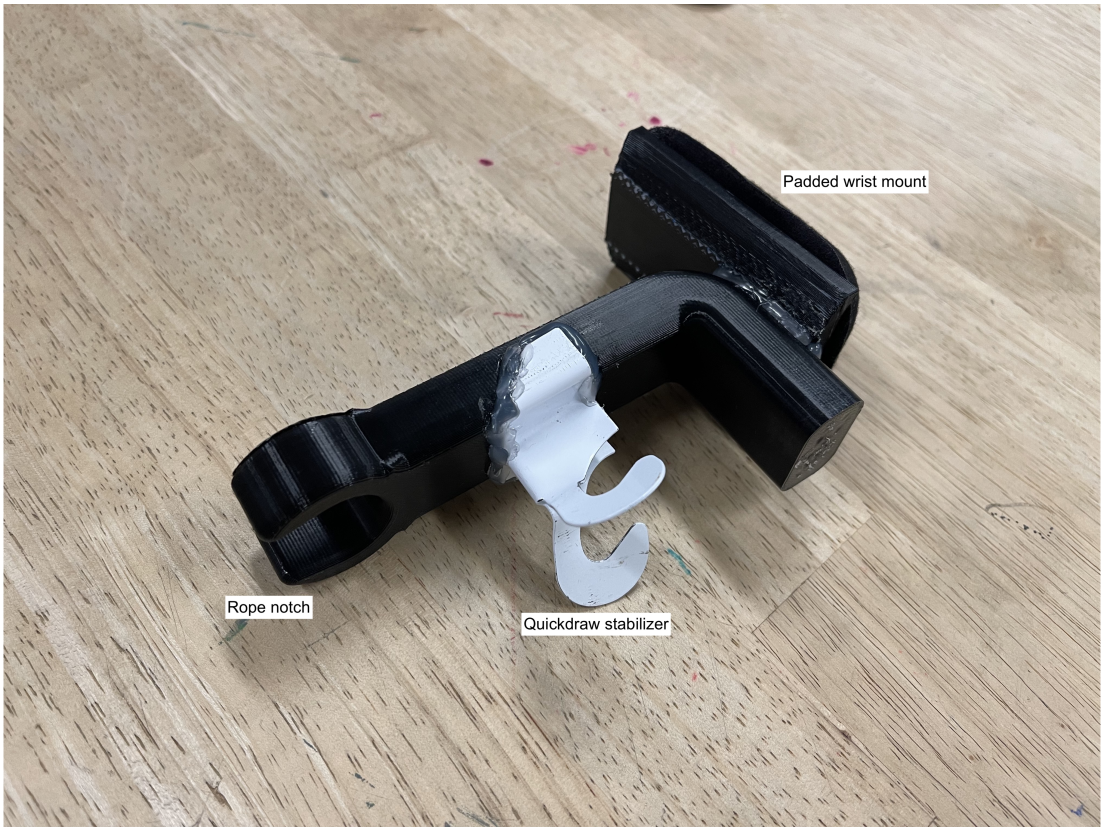

Fig. 1. Our first functional prototype. The white hook is placed in the quickdraw and the rope nests into the black notch.

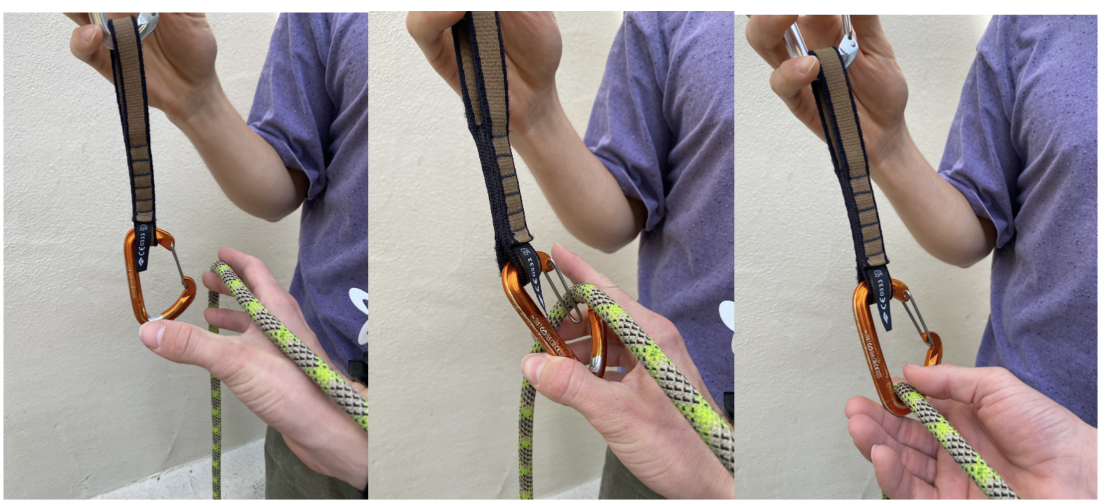

Fig. 2. A progression of normative clipping with full dexterity in the hand.

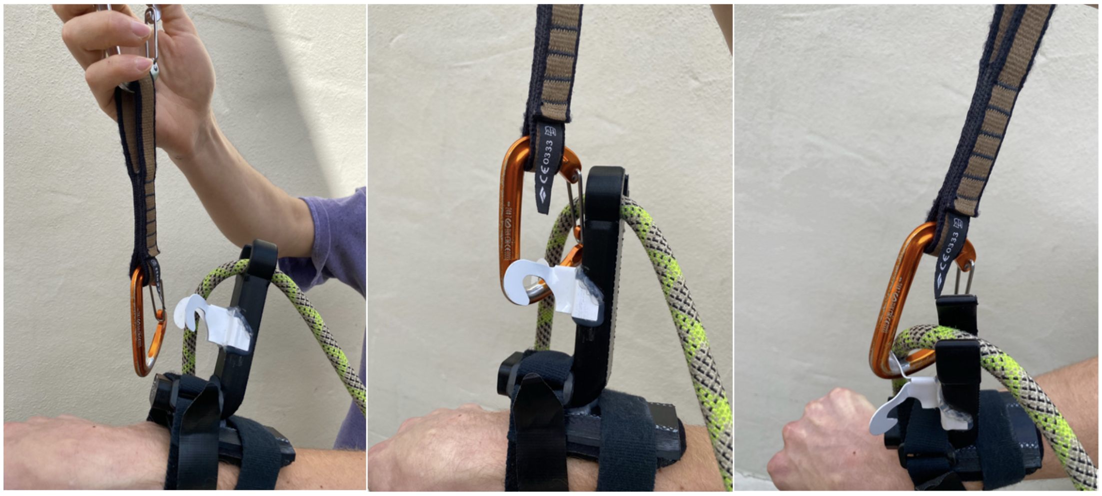

Fig. 3. A progression of clipping with the proposed device. The bottom hook will stabilize the carabiner and the rope will rest in the rope notch.

B. Test Methods

1) Preparation & Subject Selection:

Before any research is conducted, a protocol will be submitted for review through the Internal Review Board for the Protection of Human Subjects. Additionally, all participating researchers have completed the CITI training Group 1: Biomedical Research Investigators as of April 17, 2023. For this study, a sample between n=5 and n=10 AU2 climbers will be selected and general profiles of basic statistics including height, weight, wingspan, self-identified gender, and climbing experience will be recorded.

2) Data Collection:

Speed of clipping: One way to measure the effectiveness of the clipping aid is to measure the average speed with which climbers are able to clip draws on a set of common routes, first without the device, then with. Four routes would be selected, with difficulties increasing slightly for each climb. Participants would be recorded on each climb repeating once with the device and once without, and the videos reviewed to determine the average length of time it took each climber to clip with and without the device. The time will start once the climber grabs the rope and will stop once the rope is clipped into the quickdraw. A faster average clipping time with the device would indicate it is working as expected. If false, the device might increase fatigue in the climber due to the increased time spent clipping, which could increase the risk of falling.

Self-report anxiety levels while climbing: A second way to measure the effectiveness of the device is to determine if it reduces the anxiety felt by climbers on the wall. This test would be included in the same procedure as above, with the addition of an anxiety questionnaire given to participants before and after climbing. For this procedure, it would be important to alternate between giving the first attempt on a route with the device and without, as completing a route for the first time is demonstrated to cause increased anxiety levels in most climbers [8].

Post-climbing lactic acid levels: One practical way of examining the effectiveness of this device is to compare the lactic acid levels of a climber after completing a lead route using their standard clipping method and after using the device. To do so, a researcher could measure the lactic acid levels in a climbers forearm before and after the climber uses their standard clipping approach, and then allow the climber to take an ample rest period to allow for these levels to return to a baseline level. The researcher could then measure the lactic acid levels before and after the climber climbs the same climb but instead uses the device to assist in clipping. If the device is successful, lower lactic acid levels will be reported after using the device compared to using the standard clipping method. If lactic acid levels proved difficult to measure directly in the context of climbing, the researcher could use a heart rate monitor instead as a quantitative measure of exertion.

Range of motion: Another way to measure the effectiveness of the device is to determine the range of motion the climber has while clipping. An AU2 climber can typically only clip the quickdraw when it is at hip or torso level. This is due to the climber wrapping the rope around the end of their arm and sticking their arm through the carabiner. The test would follow the same procedure as the previous tests, but the distance between the torso and the quickdraw will be measured for each clip. A larger range of motion with the device could increase the safety and efficiency of a lead climb. If false, the device could increase the time it takes to clip the quickdraw or it may make the climber unbalanced, which leads to a higher risk of falling.

IV. Intellectual Merit

Our device represents an engineering solution to a practical problem faced by many climbers within the growing sport of paraclimbing. While climbing always involves some degree of inherent danger, reducing the associated risks enables more people to experience the sport. If this device does succeed in allowing people with limited hand dexterity to clip more efficiently or with less fear, lead climbing could become significantly safer for people who rely on non-traditional clipping methods. The hope for this work is that it will provide a basis from which future product designers, researchers, or hobbyists may delve deeper into assistive solutions for paraclimbers. Since this space is so new and unexplored by science, any new work helps to establish the significance of the field.

Additionally, a production version of this device may see applications beyond paraclimbing. It could be applied as a stick clipping device as it can be easily operated with one hand. The device could also be used with those learning to lead climb; if the device resulted in an easier clipping method than a traditional one, a new lead climber could isolate the elements of learning to lead climb. This would decrease time required to learn to lead as well as improve safety while learning.

V. Broader Impact

We hope to demonstrate that assistive technology can be a useful tool for rock climbing in a variety of ways, pushing past the stigma often associated with external assistance in the climbing world. Additionally, accessibility of the sport would be greatly improved. The lack of accessibility devices within lead climbing is a barrier to entry for the sport, and a first device that eliminates this barrier may pave the way for future climbing accessibility devices. This work will be made open source, as the goal of the project from the beginning has been to increase the accessibility and safety of rock climbing.

References

[1] W. Kuelthau, "Rock climbing statistics: Accidents, injuries, deaths amp; demographics," Oct 2022. [Online]. Available: https://www.99boulders.com/the-growth-of-climbing

[2] M. Simone, "Co-constructing movement and space with visually impaired people: a multimodal analysis of instructional sequences in paraclimbing trainings," *ICODOC 2017*, p. 55, 2017.

[3] C. Tan, "Guide to the paraclimbing world cup - sender one climbing," Sep 2021. [Online]. Available: https://www.senderoneclimbing.com/guide-to-the-paraclimbing-world-cup/

[4] P. B. Watts, "Physiology of difficult rock climbing," *European journal of applied physiology*, vol. 91, pp. 361–372, 2004.

[5] Rock and Ice, "How to lead climb," Mar 2021. [Online]. Available: https://www.rockandice.com/how-to-climb/how-to-lead-climb/

[6] A. Arbulu, O. Usabiaga, and J. Castellano, "A time motion analysis of lead climbing in the 2012 men's and women's world championship finals," *International journal of performance analysis in sport*, vol. 15, no. 3, pp. 924–934, 2015.

[7] D. von Essen and V. R. Schöffl, "Acute and chronic injury patterns in competitive paraclimbing sports," *American Journal of Physical Medicine & Rehabilitation*, pp. 10–1097, 2023.

[8] N. Draper, G. A. Jones, S. Fryer, C. Hodgson, and G. Blackwell, "Effect of an on-sight lead on the physiological and psychological responses to rock climbing," *Journal of Sports Science and Medicine*, vol. 7, p. 492–498, Dec 2008. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3761930/

[9] C. I. Hodgson, N. Draper, T. McMorris, G. Jones, S. Fryer, and I. Coleman, "Perceived anxiety and plasma cortisol concentrations following rock climbing with differing safety rope protocols," *British Journal of Sports Medicine*, vol. 43, no. 7, pp. 531–535, 2009.

[10] D. Giles, N. Draper, P. Gilliver, N. Taylor, J. Mitchell, L. Birch, J. Woodhead, G. Blackwell, and M. J. Hamlin, "Current understanding in climbing psychophysiology research," *Sports Technology*, vol. 7, no. 3-4, pp. 108–119, 2014.

APPENDIX A
INVESTIGATIONAL DEVICE DETAILS

Fig. 4. This is our initial prototype design. It is made to be held with a hand to test the clipping mechanism, which would later be arm-mounted.

Fig. 5. This is our prototype design once we tested the optimal geometry of the clip. It is the rope notch that holds the rope. The metal hooks and arm-mount are attached at the neck and base, respectively.