

# Climbing Shoes Versus Mountaineering Boots-What are the Effects on Physical Performance?

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## Abstract

The aim of the study was to analyze the effect of different climbing shoes (climbing shoes versus mountaineering boots) on heart rate as measure of physical performance. Five female recreational climbers ( $36.1 \pm 14.1$  years/ $180.9 \pm 6.2$  cm/ $72.6 \pm 8.5$  kg) and five male recreational climbers ( $34.4 \pm 4.9$  years/ $179 \pm 3.2$  cm/ $78.8 \pm 10.8$  kg) with regular climbing activity absolved twice a route 5b+ with climbing shoes respectively mountaineering boots. A significant increase of average heart rate from  $94.3 \pm 16.7$  to  $136.1 \pm 38.3$  beats per minute was detected when using climbing shoes ( $p < 0.01$ ). With mountaineering boots a significant increase of heart rate from  $101.8 \pm 11.4$  to  $148.3 \pm 39.5$  beats per minute was detected ( $p < 0.01$ ). End values of heart rates per minute were significantly higher when climbing with mountaineering boots versus with climbing shoes. ( $p = 0.02$ ) Interestingly, the additional exertion was taxed with  $1.75 \pm 0.5$  grades on French scale implying a serious additional challenge when climbing with mountaineering boots versus climbing shoes. In consequence, relevance of manner of shoes is pinpointed and especially when climbing several pitches in the nature for reasons of security a margin of around two levels French Scale is recommended.

**Keywords:** Climbing shoes; Mountaineering boots; Climbing skills; Heart rate

## Introduction

Sport climbing has gained increased attraction and developed from a niche sports-specially to the often found climbing halls - to a recreational sport for everybody [1]. Often, from a first contact with the sport a regular activity results with the wish to practice in the free nature and to climb several pitches or classic routes in the high alps. Luckily, deadly accidents are relatively seldom compared to hiking, mountaineering or backcountry skiing [2]. This is also a result of the fact that nowadays especially in climbing gardens routes are very well secured making sport climbing a safe way of exercising. However, especially when climbing in the high mountains e.g., the alps the

general securing points are often seldom or do simply not exist. This makes it necessary to develop a security awareness when climbing routes. Especially, when climbing in combined terrain of rock, ice and snow it is necessary to climb with mountaineering boots. However, effects of additional requirements when climbing with mountaineering boots are only partly elucidated in contrast to the knowledge of the upper body or especially arms [3-13]. Relatively broad evidence exists for effects of handhold grips combined with analysis of motoric activity of the hands and musculature whereby especially flexors of distal arm have a special relevance for climbing ability [3-13]. Generally, sport climbing performance is determined by many factors reaching from anthropometry to aerobic and anaerobic performance capacity reaching to movement system and mental component [3-13]. However, some special characteristics can be detected e.g., it is a well-known fact that sports climbing does not underly the general proportional relationship found in a lot of endurance disciplines between oxygen consumption and heart rate [14,15]. Heart rate increases disproportional compared to oxygen consumption yielding to several theories about the underlying mechanism from psychological to physiological explanations [14,15]. However, especially heart rate was given special attention as indicator of physical exhaustion [14,15]. When trying to develop an understanding of the effects of different shoes on climbing abilities it is to mention that Climbing with mountaineering boots definitely yields due to the higher shoe weight to a necessary additional muscle work and stronger usage of cardiovascular system [16-18]. Relevance of kind of shoe type underlying it is generally accepted that shoes are often worn too tight by climbers while increasing performance but unfortunately increasing injury risks [19-21]. This yields to the aim of the study which can be formulated in the following way: how are effects of different shoe type to tax for the cardiovascular system due to wearing mountaineering boots instead of climbing shoes? What kind of recommendation can be made especially when climbing in the free nature and in combined terrain? What recommendations can be made concerning security? As hypothesis with potential falsification it shall be postulated that no effect from manner of shoe type climbing shoes versus mountaineering boots can be detected [22].

## Materials and Methods

### Participants

Five male ( $34.4 \pm 4.9$  years/ $179 \pm 3.2$  cm/ $78.8 \pm 10.8$  kg) and five female climbers ( $36.6 \pm 16.7$  years/ $169.4 \pm 6.1$  cm/ $62.6 \pm 7.3$  kg) absolved a climbing route of difficulty 5b+ with climbing shoes respectively mountaineering boots. Participants were advised to be rested and under normal diet. The study was conducted in the sense of good clinical practice and in accordance with the local requirements of the ethics committee.

### Measurements and testing procedures

Climbers absolved a route of difficulty 5b+ starting with climbing shoes respectively mountaineering boots. While climbing heart rate and BORG-Scale (6-20) was questioned [23]. Furthermore, the increase of difficulty (how much levels on French Scale) due to mountaineering boots instead of climbing shoes was questioned.

### Gear

Participants were equipped with heart rate measurement Polar M600 (Polar, Zug, Switzerland) allowing to continuously measure heart rate and to export data into an excel sheet allowing to make analyses of changes of heart rate over time.

### Statistical procedures

For the two measurements mean and standard deviation of heart rate was calculated as well as for the reported values of BORG-Scale. In order to detect differences between start- and end values two-sided, paired t-Tests were conducted. [24] Calculations and analyses were conducted with Graphpad Prism (GraphPad Software, Inc., La Jolla, California, USA) and Microsoft Excel (Microsoft Inc., Redmond, Washington, USA).

## Results

**Table 1** shows the start and end values of the climbed routes 5b+ (French Scale) for the whole sample. Concerning alterations of heart rate from the beginning of climbing to the end a highly significant increase can be detected ( $p < 0.01$ ). The same pattern of an increase can also be found with mountaineering boots ( $p < 0.01$ ). Between the start values no significant difference between climbing shoes versus mountaineering boots can be detected ( $p = 0.167$ ), however when comparing the average heart rate per minute in the end of climbing the routes with climbing shoes respectively mountaineering boots a significant difference can be detected. ( $p = 0.02$ ) Furthermore BORG-values in the end of climbing a route with mountaineering boots are significantly higher with values of  $12.9 \pm 4.2$  versus with climbing shoes with  $10.2 \pm 2.1$  ( $p = 0.017$ ). Furthermore, the increase of difficulty due to climbing with mountaineering boots was taxed with  $1.75 \pm 0.5$  Grades on French Scale.

**Table 1** Start and Endvalues of climbed routes 5b+ with climbing shoes and mountaineering boots.

Heart Rate	Start values of heart rate (beats/min)	End values of heart rate (beats/min)	Change in heart rate (beats per minute)
	Mean $\pm$ SD	Mean $\pm$ SD	
Route 5b+ with climbing shoes	94.3 $\pm$ 16.7	136.1 $\pm$ 38.3	61
Route 5b+ with mountaineering boots	101.8 $\pm$ 11.4	148.3 $\pm$ 39.5	44.5

Between the start values no significant difference between climbing shoes versus mountaineering boots can be detected ( $p = 0.167$ ), however when comparing the average heart rate per minute in the end of climbing the routes with climbing shoes respectively mountaineering boots a significant difference can be detected ( $p = 0.02$ ).

## Discussion

The study conducted aimed to analyze effects of climbing shoes versus mountaineering boots on climbing skills respectively heart rate. In order to quantify effects ten climbers with good recreational sports level absolved a route 5b+ French Scale with climbing shoes respectively mountaineering boots. The increase of heart rate was significantly higher with mountaineering boots compared to climbing shoes. Generally, an increase of values from 129 to 180 beats per minute is reported allowing to order in the results in the middle and in consequence speaking for a general good validity of the results [3,14,15,25]. Although some advantages results from mountaineering boots (normally not too tight in contrast to

climbing shoes e.g., when securing climbing partner) precision is reduced and the possibility to find grip is more difficult while increasing biomechanical requirements implying a larger work load yielding to an increased heart rate [1,16,17]. The difference of around 4 beats per minute given a stroke volume of around 150 mL (approximated as a result of training state and degree of physical activity) an increase of heart rate volume of 600 mL per minute results [26,27]. Given the fact of a maximum heart rate volume of 30 Liters per minute and the degree of physical activity and the fact that in rest state around 10 liters are used (Starting values of heart rate around 100) a reserve of heart rate volume of around 20 Liters per minute results. In consequence, climbing with mountaineering boots instead of the light climbing shoes requires nearly ten percent of free heart rate volume and in consequence of physical performance. [26,27] Concerning the effects of an increase of heart rate is to mention that due to changing force point differing when using mountaineering boots instead of climbing shoes [7]. The question cannot finally be answered if the additional increase in heart rate is an effect of increased weight or different coordination requirements. Undoubtedly when climbing up an increased performance is

necessary due to the higher shoe weight (higher potential Energy to be performed - Energy [kJ]=mass [kg] × height [m] × gravity constant [m/sec<sup>2</sup>]) In consequence only due to the effect of weight neglecting other factors a higher physical performance is necessary when climbing with mountaineering boots. It is likely to expect that in demanding overhang parts the effects of alterations of heart rate is even larger, especially when only small grips exist in a route. Probably less relevant is the wearing of mountaineering boots in terrain with moderate difficulty due to the lack of necessity to use small grips.

## Practical Implications

Climbing with mountaineering boots is associated with an increased requirement of cardiovascular system and therefore climbing with mountaineering boots yields to a larger usage of cardiovascular system compared to climbing with classical climbing shoes.

The relevance of kind of shoes for climbing is underlined. Especially in the free nature (slab climbing) and when climbing several pitches effects could even become more pronounced. For security reasons based on these findings the usage of a security margin of around 2 degree on French Scale is recommended when climbing with mountaineering boots.

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