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Backpack Load Influences Heart Rate While Climbing

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Abstract

Objectives: The aim of this study was to analyze effects of backpack loads on heart rate while climbing.

Material and methods: A first sample of climbers absolved a 5b route (French scale) without a backpack and with 5, 10 and 15 kg load. To further analyze effects of climbing difficulty a second sample of climbers absolved two routes with difficulty of 5b respectively 5c (French Scale) without and with a load of 10 kg.

Results: In the first sample increases of heart rate from 97.6 ± 14.4 to 146.0 ± 15.1 with no load, 105.9 ± 14.7 to 154.7 ± 14.6 with 5 kg load, 108.2 ± 16.2 to 162 ± 14.2 with 10 kg load, 111.2 ± 9.9 to 170.2 ± 9.9 with 15 kg load were detected ($p<0.01$). In route 5b average heart rate increased from 99.8 ± 15.5 to 146.3 ± 23.7 without respectively 102.4 ± 22.8 to 164.1 ± 22.7 with 10 kg load ($p<0.01$). In route 5c an increase from 99.6 ± 11.9 to 145.1 ± 24.0 without respectively from 102.0 ± 26.6 to 164.1 ± 19.2 with 10 kg load was detected ($p<0.001$).

Conclusions: Analyses indicate that an increase of 1 kg in backpack load leads to an increase of heart rate of 1-2 beats per Minute independent from climbing difficulty.

Keywords: Backpack load; Climbing; Heart rate; French scale; Climbing security

Introduction

Sport climbing has become more and more popular in Central Europe and developed from a classic niche sport mainly used as training mean for difficult routes in the Alps to a recreational sport for everybody [1-3]. Due to the emergence of numerous climbing walls in urban regions this yielded to the possibility of physical activity from juniors to seniors or the whole family. Often from a first contact with the sport in a climbing hall regular climbing activity results with the aim to climb difficult routes in the nature, fortunately, concerning deathly accidents in contrast to hiking, backcountry skiing or mountaineering these events are relatively seldom [4]. This is probably due to progress in security standards and many routes in the nature and especially in climbing gardens are nowadays very good secured. However, especially when climbing in the high Alps securing is only partly possible making it necessary to have developed good abilities of self-estimation. Especially for climbing routes with several pitches the wearing of a backpack and the carrying of technical material is necessary while constant fixing points are often missed in such routes. Undoubtedly climbing performance is determined through many factors from anthropometric to aerobic and anaerobic capacity of skeletal muscle to the mental component, whereby for high level climbing especially the force of the finger and the lower arm flexor seems to play a key role. Climbing with a backpack results in a higher work load and therefore getting along with a change of biomechanical requirements and the need to perform on a higher rate [5-7]. Concerning energy consumption when walking with a backpack a proportional increase of metabolic costs to load was described. Furthermore, backpack wearing influences ventilator conditions (e.g., breathe frequency) yielding to total higher performance demands [8-10]. These hints can be deciphered mainly from classical movement patterns from walking or running with different loads. While climbing through the displacement of the center of gravity-away from the rock wall-higher physical requirements result **(Figure 1)**. As a consequence of the displacement of gravity center forces become larger (lever rules) and especially overhanging parties become more challenging. Furthermore, the wearing of a backpack changes the muscle-activation pattern of the extremities. Backpacks with very high load change the movement pattern and forces on vertebra getting larger [11-13].

Figure 1 Through carrying of a backpack physical requirements are increased through the additional weight with increased physical work necessary and through the change of the center of gravity backwards and upwards (blue arrow), gravity force (red arrow) is centered more backward, overhanging parts and fast climbing become an additional challenge.

From the mentioned it can be derived that a backpack yields to higher performance requirements while climbing [14-17]. The above mentioned yields to the aim of the study to analyze effects of different backpack loads on heart rate while climbing, as Hypothesis with potential falsification it shall be stated that no effects of backpack load on heart rate can be detected [18-21].

Materials and Methods

Participants

A first sample of thirteen male recreational climbers (42.3 ± 19 years/172.3 ± 5.4 cm/67.4 ± 6.8 kg) climbed a 5b with no backpack and a backpack with a load of 5, 10 and 15 kg. For analyzing effects of difficulty a second sample of twelve good (on-sight level 5b French Scale or more) male climbers (36.1 ± 14.1 years/180.9 ± 6.2 cm/72.6 ± 8.5 kg) absolved two climbing routes with difficulty 5b respectively 5c with a backpack of 10 kg. Participants were advised to be rested and under normal nutrition. From all participants informed consent was obtained. Study was conducted in the sense of good clinical practice [22-25].

Field measurements

The first sample of thirteen male climbers absolved the route 5b with and without a backpack of 5, 10 and 15 kg load yielding to a total of 4 measurements. The second sample of twelve climbers absolved one route with difficulty of 5b respectively 5c alternating the start with packing respectively without packing yielding to 4 measurements. Before start climbing backpack from **(Figure 1)** was loaded with the respective weight (water bottles). Between climbed routes climbers waited at least till subjective recovery was reported [26-29].

Equipment and gear

Participants were heart rate monitored with Polar M400 (Polar Corp., Zug, Switzerland) and a Mammut Flight 28 backpack (Mammut Corp/Seon/Switzerland). Heart Rate allowed observing heart rate continuously and allowed with special software to export data to an excel file for further statistical analyses [30-33].

Statistical analysis

For both samples and all climbed routes mean and standard deviation of start and end values were calculated. For analyzing differences between start and end values heart rate was analyzed with two-sided paired t-tests. Differences between sample 1 and sample 2 of start- and end values for route 5b without load and 10 kg load were calculated with two-sided heteroscedastic t-tests. Calculations were conducted with Graphpad Prism (GraphPad Software, Inc., La Jolla, California, USA) and Microsoft Excel (Microsoft Inc., Redmond, Washington, USA).

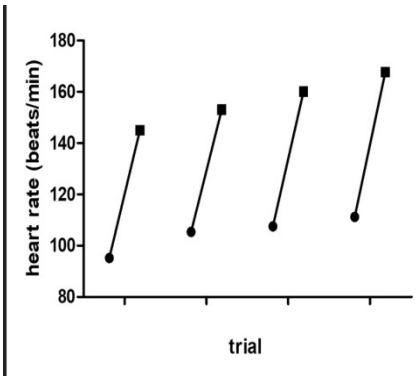

Figure 2 Average start values (left) versus end values (right) without backpack and with 5 kg, 10 kg and 15 kg backpack. Differences between start and end values are all highly significant ($p<0.001$) the weight increase.

Results

Table 1 shows the start and end values of the climbed routes for the first sample and **Table 2** shows the start and end values of the climbed routes for the second sample. It is shown, that in route 5b as well as 5c an increase of around 60 beats per minute result when wearing a 10 kg backpack ($p<0.001$) **(Figure 2)**. In start and end values without a backpack of 10 kg a smaller increase of around 45 beats per minute result ($p<0.001$), differences in both routes 5b and 5c

are therefore around 15 beats per Minute when climbing with a backpack of 10 kg load.

Table 1 Start and end values of heart rate while climbing route 5b with no backpack and with 5, 10, 15 kg load. In all four cases start and end values are highly significant different ($p<0.001$). Increase in heart rate per minute was calculated from individual values resulting in somehow different values as when subtracted reported end versus start values (n=13).

Heart Rate while climbing route 5b	Start value	End value	Increase heart rate per Minute
without load	97.6 ± 14.4	146.0 ± 15.1	48.5 ± 13.4
with 5 kg load	105.9 ± 14.7	154.7 ± 14.6	48.8 ± 12.6
with 10 kg load	108.23 ± 16.2	162 ± 14.2	53.8 ± 12
with 15 kg load	111.2 ± 9.0	170.2 ± 9.9	57.3 ± 11.9

Analyzing values from **Table 2** in detail reveal that despite alterations of climbing patterns (5b versus 5c/with and without backpack) start values of heart rate increased during trials. These small increases are probably due to the fact that measurements were made before climbing start but after grabbing the backpack representing the additional weight. Furthermore, analyses of differences in sample one and two were conducted and heart rate values of route 5b without backpack and with 10 kg load were compared with two-sided heteroscedastic t-test. No significant differences could be detected between the increase of the heart rate in route 5b without load for the two samples ($p=0.725$) and for 10 kg load in route 5b ($p=0.186$).

Table 2 Start and End values of route 5b and 5c (n=12).

Heart rate while climbing	Start value	End value	Increase heart rate per Minute
5b without load	99.8 ± 15.5	146.3 ± 23.7	46.6 ± 12.9
5b with load	102.4 ± 22.8	164.1 ± 22.7	61.7 ± 16.3
5c without load	99.6 ± 11.9	145.1 ± 24.0	45.5 ± 20.7
5c with load	102.0 ± 26.6	164.1 ± 19.2	62.1 ± 24.3

Discussion

The here conducted study aimed to analyze the effects of wearing a backpack while climbing. Therefore, a first sample of thirteen climbers absolved a 5b route without a backpack and with a load of 5, 10 and 15 kg. In order to analyze effects of difficulty a second sample absolved two routes with difficulty 5b respectively 5c. In contrast to other findings, no effect of climbing difficulty on heart rate could be detected. The second part of the study aimed to explore the effects of different backpack loads of 5 kg, 10 kg, and 15 kg on heart rate. It came obvious that the higher the increase in load, the higher the increase in heart rate allowing falsifying the stated hypothesis. However, climbers with highly differing performance levels can have the same response in heart rate when climbing due to different hemodynamic responses (differences in stroke volume or hematocrit), pulmonary parameters or efficiency of use of oxygen in skeletal muscle. From a theoretic point, physical performance is directly proportional to weight e.g. an increase in heart rate from 5 to 10 kg and 10 to 15 kg should be the same under the assumption of constancy of other parameters such as stroke volume. However in reality, effects such as change of mass of gravity, reduction of total performance through pulmonic parameter or effects on body temperature must be kept in mind increasing performance requirements when climbing with backpack in tendency. Furthermore, results probably become more pronounced for routes with negative angles or overhanging parts due to stronger gravity force development **(Figure 1b).** Probably in routes with moderate difficulty effects of wearing a backpack become smaller due to the increase of friction lowering effects of additional weight.

Focusing on packing recommendations it´s likely to presume that the optimal wearing of a backpack respectively the smart packing is crucial, it was shown that through additional tail fixation metabolic load is decreased due to better ergonomy when walking While climbing this seems to be even more important as it was shown that ergonomy determines strongly cardiovascular intensity. Furthermore, from a biomechanical point of view it should be kept in mind that when wearing a backpack of more than ten percent of body weight intensity especially for vertebra increases. Weight should especially in children and adolescents, not increased to more than ten percent of body in order to harm damages on vertebra.

To sum up its allowed saying that based on measurements independent of difficulty one additional kg of weight results in an increase of around 1.5 beats per Minute. Astonishingly, even experienced climbers of the sample in principle easy routes reported orally that for them backpack altered climbing pattern stronger than expected. To keep in mind in difficult routes in combined area and over several days backpack is

without doubts even heavier than 15 kg (crampoon, ice tools or pickle, tea, food) The management of weight therefore gets important for climbing routes in the high-alps.

Conclusions

When wearing a backpack of 10 kg and increase of heart rate independent of difficulty (5b versus 5c) of around 15 beats per Minute result-respectively an additional kg leads to an increase in heart rate by around 1 to 2 beats per minute.

This fact becomes important when climbing in the nature or when climbing several pitches makes it necessary to climb with a backpack and the necessity of wise packing.

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