

# The Borg Scale at high altitude

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A – the preparation of the research project

B – the assembly of data for the research undertaken

C – the conducting of statistical analysis

D – interpretation of results

E – manuscript preparation

F – literature review

G – revising the manuscript

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## Article history:

Received: 28.04.2021

Accepted: 16.05.2021

Published: 18.06.2021

## DOI:

10.5604/01.3001.0014.9500

## Abstract

**Introduction:** The Borg Scale for perceived exertion is well established in science and sport to keep an appropriate level of workload or to rate physical strain. Although it is also often used at moderate and high altitude, it was never validated for hypoxic conditions. Since pulse rate and minute breathing volume at rest are increased at altitude it may be expected that the rating of the same workload is higher at altitude compared to sea level.

**Material and methods:** 16 mountaineers were included in a prospective randomized design trial. Standardized workload (ergometry) and rating of the perceived exertion (RPE) were performed at sea level, at 3,000 m, and at 4,560 m. For validation of the scale Maloney-Rastogi-test and Bland-Altman-Plots were used to compare the Borg ratings at each intensity level at the three altitudes;  $p < 0.05$  was defined as significant.

**Results:** In Bland-Altman-Plots more than 95% of all Borg ratings were within the interval of 1.96 x standard deviation. There was no significant deviation of the ratings at moderate or high altitude. The correlation between RPE and workload or oxygen uptake was weak.

**Conclusion:** The Borg Scale for perceived exertion gives valid results at moderate and high altitude – at least up to about 5,000 m. Therefore it may be used at altitude without any modification. The weak correlation of RPE and workload or oxygen uptake indicates that there should be other factors indicating strain to the body. What is really measured by Borg's Scale should be investigated by a specific study.

**Keywords:** Borg Scale, perceived exertion, high altitude, exercise physiology, exercise testing

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## Introduction

Since Borg and Dahlström published the first version of their rating system in the 50s the system was modified several times and is now well established to rate perceived exertion in sports, but also by patients [1-4]. The actual scale consists of 15 grades with “6” indicating “very, very low exertion” to “20” indicating “extreme exertion, individual limit” (Tab. 1) [3]. The investigator may use the pulse rate to check the plausibility of the rating, since the given value should be approximately 1/10 pulse rate [3]. When persons are accustomed to the scale, the procedure gives valid data (surveyed in [1,3]). It must be pointed out that Borg’s scale rates perceived exertion (RPE) which is a complex psychophysiological topic and not just the direct consequence of workload [3]. Therefore this rating is within the subjective sphere of the proband or patient and when he / she informs the investigator about the rating this person gets information how the patient rates the severity of his / her work [2].

**Table 1.** Borg’s scale of perceived exertion as used in this study [4], [3]

Rating	Verbal description	Metabolism of a moderately trained collective
7	Very, very easy	Pure or mainly aerobic energy metabolism
8		
9	Very easy	
10		
11	Easy	
12		
13	A bit strenuous	Aerobic-anaerobic transition
14		
15	Hard	Anaerobic metabolism predominates, lactate accumulation
16		
17	Very hard	
18		
19	Extremely hard (maximum)	

However, pulse rate (HF), breathing frequency (rsp) or minute volume, peripheral exhaustion (lactate concentration), and possibly other factors, which may be important when the perceived workload is rated, are increased at moderate or high altitude or in isobaric hypoxia. This may cause a bias and the need of a correction factor, when the scale is used at altitude. Another effect may also cause a bias: since maximal aerobic workload decreases above 1,500 m by 10-15% per 1,000 m [5-7], a given workload may cause a higher perceived exertion than the same

workload in normoxic conditions. However, with regard to the stress-strain-model of Rohmert and Rutenfranz [8], it must be noted that Borg’s method is an approach to scale subjective strain, although this is still a debated topic (e.g. [9]). This is important because several authors often postulate that the rating is directly linked to oxygen uptake or workload, which would be “stress” in the Rutenfranz-model, not “strain”.

We therefore investigated whether Borg’s scale gives valid data at sea level (SL), moderate altitude (MA, 3,000 m), and high altitude (HA, 4,560 m) with a complex cross-over design to exclude any effect of acclimatization. The study was fully accepted by the Ethical Commission of the University of Düsseldorf (No. 950).

## Material and methods

16 healthy mountaineers (non-smokers, mean age 31.1 years [median 26, range 19-49], mean body mass index 22.6, median 23.7, range 19.6-32.2) who had not stayed above 1,500 m for at least two months before the study were enrolled. Inclusion criteria were: no cardiopulmonary disease or any disease or disability which does not allow spiroergometry, no medication during the study (especially no medication which may influence performance or breathing at altitude like theophylline, acetazolamide, or sildenafil), no alcohol for at least 24 hours before measurements. The participants were advised and surveyed to avoid any exhaustive activity between the measurements. Although all participants were said to be non-smokers CO hemoglobine was measured (ABL 520; Radiometer, Copenhagen). All participants were surveyed for the absence of altitude disease and for thermal comfort. To exclude diurnal effects all investigations were performed at the same time of day (+/-2 hours). All subjects were trained to use the Borg rating system.

The participants were randomly assigned to one of two different altitude profiles. The two altitude profiles were,

1. Sea level (SL) – moderate altitude (MA, 3,000 m) – SL – high altitude (HA, 4,560 m) – SL.
2. SL – HA – SL – MA – SL.

MA took place at Trocker Steg, Zermatt, Switzerland (3,000 m) while HA was measured at Margherita Hut, Monte Rosa (4,560 m).

At all of the five measurements mentioned above a spiroergometry (cycling ergometer Ergomed 840 (Siemens, Erlangen, Germany), Corina Cord Integrated Amplifier and CardioSoft V.2.1 (Marquette-Hellige Medical Systems, Freiburg, Germany), Cosmed K4 RQ and Cosmed K4 Win/EE software (Cosmed Ltd., Rome, Italy), was performed according to the Hollmann scheme, starting at 40W with additional 40W every three minutes until exhaustion [10]. In the third minute steady-state

conditions were achieved [10] and the subject was asked to rate his / her exertion according to the Borg scale. The type of scale used here is shown in Tab. 1.

Data are presented as mean  $\pm$  standard deviation. To detect any effect of acclimatization, the data at SL were descriptively checked for a shift. Additionally both groups were compared at MA and HA. To assess deviation in accuracy between the Borg ratings of the same workload at different altitudes, paired *t*-test was applied. To describe the clinical relevance, the corresponding 95% confidence interval for the mean deviation in accuracy was computed. The precision of measurements were compared by means of Maloni-Rastogi-tests. Bland-Altman-plots were used to graphically explore deviation in accuracy, differences in precision, and agreement between ratings.

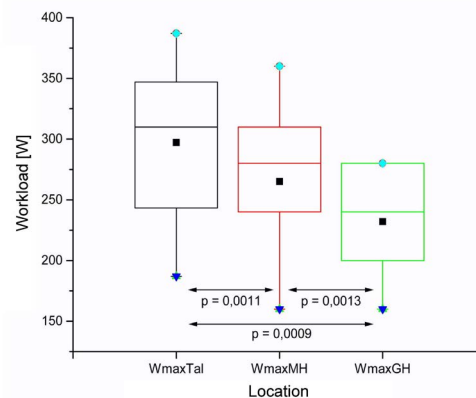
Because of the exploratory nature of the study an adjustment to the significance level for multiple testing was not necessary in contrast to confirmatory trials [11]. The paired *t*-test and the corresponding confidence interval approach are used to assess deviations in location of Borg Scale measurements at two different levels. The test procedures of Maloney and Rastogi are used to assess the comparison of precisions of Borg Scale measurements at two different levels. The Bland-Altman plot is a graphical description of the agreement between Borg Scale measurements at different levels.

All tests were two-sided and assessed at the 5% significance level. Because of the exploratory nature of the study, no adjustments were made to the significance level to account for multiple testing. All statistical analyses were performed using SAS® statistical software, V9.2 (SAS Institute, Cary, NC, USA) under Windows XP.

## Results

There were no differences between both subgroups which might indicate an influence of the different altitude profiles. There was also no shift of the SL values during the study. Therefore the following results are based on the whole collective. Body weight and haematocrite were constant ( $< \pm 2\%$ ) indicating a constant hydration status. CO-Hb was  $< 0.5\%$  and therefore negligible.

As expected, there was an increase of mean HF at rest with increasing altitude. From MA to HA this increase was  $+9.5/\text{min}$  or  $+11.4\%$ , respectively ( $p < 0.05$ ). There is no significant difference of mean lactate at rest between SL ( $1.3 \pm 0.74 \text{ mmol/l}$ ) and MA ( $1.5 \pm 0.36 \text{ mmol/l}$ ), but there was a significant difference at HA ( $2.2 \pm 0.74 \text{ mmol/l}$ ;  $p < 0.002$ ). This corresponds to  $+31\%$  per 1,000 m above 1,500 m. There was no difference of mean maximal lactate at all altitudes (SL  $9.2 \pm 2.37 \text{ mmol/l}$ ; MA and HA  $9.6 \text{ mmol/l}$  [ $\pm 2.92$  resp.  $2.06$ ]). Maximum workload showed a decrease with altitude (Fig. 1).



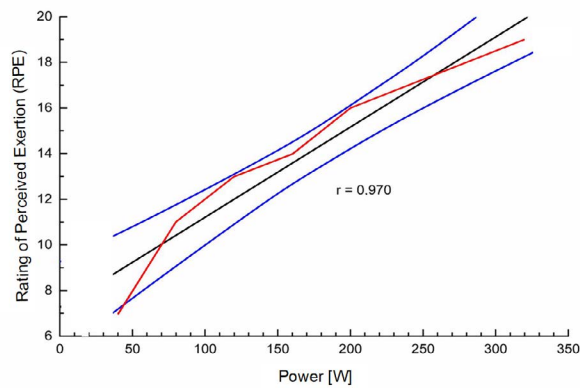
**Figure 1.** Maximum workload of the collective at the altitudes measured

The difference between SL and MA was 10.6% ( $p = 0.001$ ) and between SL and HA 21.4% ( $p = 0.0009$ ). The respective results concerning pulse work capacity (PWC) are given in Tab. 2.

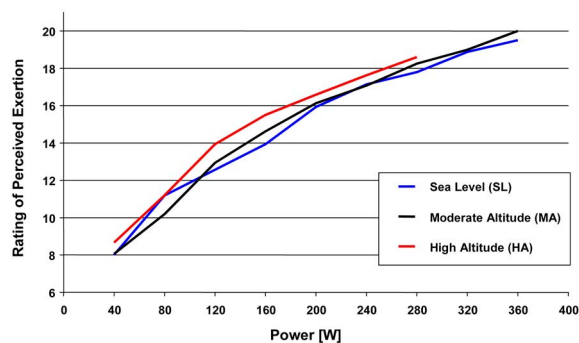
**Table 2.** Pulse work capacity (PWC) in W/kg body weight of the collective at different altitudes. The numbers behind PWC indicate the respective pulse rate, those in brackets the number of probands

Altitude	PWC100	PWC130	PWC150	PWC170
SL	$0.8 \pm 0.3$ (16)	$1.8 \pm 0.3$ (16)	$2.4 \pm 0.4$ (16)	$3.1 \pm 0.5$ (16)
MH	$0.5 \pm 0.4$ (16)	$1.5 \pm 0.4$ (16)	$2.2 \pm 0.5$ (16)	$2.8 \pm 0.6$ (16)
HA	$0.0 \pm 0.4$ (15)	$1.0 \pm 0.3$ (15)	$1.7 \pm 0.4$ (15)	$2.3 \pm 0.6$ (15)

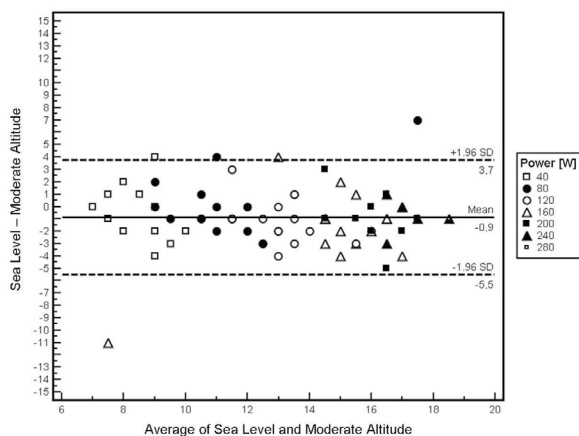
All participants reported reliable data at any altitude when rating according to Borg's scale. An example (subject no.13) is given in Fig. 2; all data are within the 95% confidence interval. An example for the rating at different altitude is shown in Fig. 3. This illustrates a general tendency to a minimal (not significant) higher rating of the respective workload with altitude, which corresponds to  $+1.0$  to  $2.8\%$  per 1,000 m above 1,500 m. The comparison of the data from SL and MA by Bland-Altman-Plot is shown in Fig. 4. Only two of all measurements are considered as outliers. All the other data are near the mean of  $-0.1$  which indicates that the subjective rating at MA was not significantly higher than at SL. Values above mean indicate that the rating was higher at SL and vice versa below mean.



**Figure 2.** Correlation of an individual's (No.13) rating of perceived exertion (Borg scale) and the workload at SL. Data in red, regression line in black, 95% interval in blue



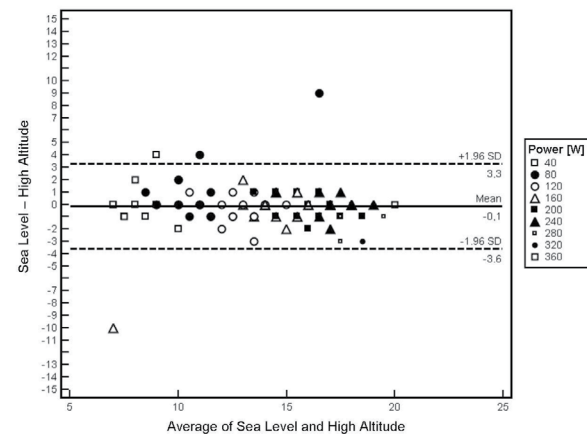
**Figure 3.** Correlation of the mean ratings of perceived exertion (Borg Scale, total collective) and the workload at different altitudes



**Figure 4.** Bland-Altman-plot to compare the correlation of the ratings between SL and MA

Fig. 5 outlines the comparison between SL and HA, which is the greatest altitude difference investigated in the study. Again only two data should be interpreted as outliers. The mean of

$-0.9$  and the limits of agreement of  $+3.5$  and  $-5.5$  indicate a slightly higher rating at HA (n.s.) and a higher variability of the subjective rating (n.s.). When a comparison between MA and HA was performed analogue to Fig. 4 and Fig. 5 all data are within the confidence interval with the mean at  $-0.8$  and the limits of agreement at  $+2.4$  and  $-3.9$ . Statistical details about the Bland-Altman-Plots and the Maloney-Rastogi-test are shown in Tab. 3.



**Figure 5.** Bland-Altman-plot to compare the correlation of the ratings between SL and HA

## Discussion

We investigated the validity of the rating of perceived exertion when using the Borg Scale at altitude. Our data indicate that Borg's scale is valid at least until about 5,000 m. This result also validates retrospectively all altitude studies, where this scale of exertion has been used, but the authors did not realize that the scale has never been validated at altitude before.

The study and parameters which might have some influence on the results (e.g. CO-Hb, which may decrease  $VO_{2max}$  at moderate altitude even at relatively low concentrations of 3.4% [12] or caffeine, which significantly increases performance at altitude even more than at sea level [13]) were standardized as much as possible and the data indicate that there was no influence of these factors. The comparison of the results obtained three times at sea level showed that the short time of altitude exposure did not cause a bias by acclimatization. The relative large range of the age of the group did also not cause a bias because the perceived exertion does not change with age in adults [14].

The validation of the scale at altitude is of special interest at least for two reasons: 1) although not validated for such conditions it has been used in several studies (e.g. [5, 15-21]), but without validation of the method the results of these studies are

**Table 3.** Statistical details about the Bland-Altman-Plots and the Maloney-Rastogi-test

Workload [W]	N	Mean of ratings	Standard deviation	<i>p</i> ( <i>t</i> -Test)	95% confidence interval	<i>P</i> (Maloney-Rastogi-test)
<b>a) SL vs. MA</b>						
40	16	-0.063	1.389	0.860	[-0.803; 0.678]	0.930
80	16	1	2.503	0.131	[-0.334; 2.334]	0.002
120	16	-0.375	1.088	0.188	[-0.955; 0.205]	0.521
160	16	-0.688	2.676	0.321	[-2.114; 0.739]	0.001
200	15	-0.133	0.990	0.610	[-0.682; 0.415]	0.223
240	13	0	0.817	1.000	[-0.493; 0.493]	0.550
280	8	-0.875	0.991	0.041	[-1.704; -0.050]	0.753
320	3	-1	1.732	0.423	[-5.303; 3.303]	1.000
360	1	-	-	-	-	-
<b>b) SL vs. HA</b>						
40	15	-0.600	2.063	0.279	[-1.743; 0.543]	0.271
80	15	0.133	2.560	0.843	[-1.284; 1.551]	0.063
120	15	-1.267	1.870	0.020	[-2.302; -0.231]	0.176
160	14	-1.857	3.461	0.066	[-3.855; 0.141]	0.052
200	11	-0.818	1.991	0.203	[-2.156; 0.519]	0.217
240	7	-0.714	1.254	0.182	[-1.874; 0.445]	0.956
280	3	-1.333	0.577	0.057	[-2.768; 0.101]	< 0.0001
<b>c) MA vs. HA</b>						
40	15	-0.533	1.642	0.230	[-1.442; 0.376]	0.280
80	15	-0.933	1.668	0.048	[-1.857; -0.010]	0.199
120	15	-0.800	1.613	0.075	[-1.693; 0.093]	0.150
160	14	-0.929	1.774	0.072	[-1.953; 0.096]	0.069
200	11	-0.727	1.794	0.209	[-1.932; 0.478]	0.267
240	7	-0.714	1.704	0.310	[-2.291; 0.86]	0.465
280	3	-0.333	1.155	0.667	[-3.202; 2.535]	-

questionable, and 2) a large number of persons needs to monitor the actual level of exercise at altitude (e.g. persons with pre-existing diseases, mountaineers, athletes during altitude training).

There are only a few studies which indirectly indicate that the Borg rating may be valid at altitude and that some factors, which may be expected to be important to influence the perceived exertion of the subjects, are of minor or even of no influence. At 0 m (400 m), 1,400 m, 4,880 m, and 5,550 m, SaO<sub>2</sub> and Borg rating was measured at a small collective to quantify the shortness of breath at high altitude. There was no difference of the Borg rating in both subgroups (*n* = 7 each) at all altitudes, but the studies were underpowered [22]. Another study included 6 patients with liver transplantation and 14 controls of similar age, BMI and training status [23]. When they climbed Mt. Kilimanjaro (5,890 m) 83% of the patients and 84.6% of the controls summited. There was no difference in HF, SaO<sub>2</sub>, and Borg rating between both groups. The only difference was

the hypertensive situation which developed in the patient group when they climbed above 3,950 m.

However, these studies did not systematically evaluate the validity of the procedure at altitude. In contrast, our actual study systematically investigated this problem and the scale was proved to be valid at least up to about 5,000 m. The minimal inter- and intra-individual differences and the differences between the different altitudes may be interpreted as natural differences of the physical and mental state of the probands on the days of testing.

Several authors assume that the subjective rating of workload ("strain") mainly depends on oxygen consumption. This is questionable since the higher the level of exercise the more anaerobic metabolism comes into play. Another problem is that neither Borg nor anybody else ever has investigated in detail which parameter is measured by the scale and predominantly indicates workload (= "strain") to the body. The fact that the

respective workload was rated similar at different altitudes – which was not expected when the study was planned but which is in accordance with others (e.g. [22]) – showed that  $pO_2$  or  $VO_2$  and their decrease with altitude are obviously not the predominant factors to indicate workload to the subject. Other factors should be also taken into account, e.g. the physiological increase of systolic blood pressure with increased exercise. This is directly linked to the right cerebral hemisphere (R. Waanders, Bregenz, Austria, personal communication). However, this analysis is beyond the scope of the actual study. Nevertheless, our actual data indicate a weak correlation between oxygen uptake and the (subjective) rating of strain according to Borg's Scale and that other mechanisms may be more important (Küpper et al., in preparation).

The study was performed at healthy volunteers only. This was a condition given by the ethical commission since there were not yet enough data for such a study with patients. Therefore the study proves that the procedure is valid for healthy persons. The results may differ in patients whose oxygen uptake is limited for any reason (e.g. cardiopulmonary diseases) or when the specific side effects of drugs may alter exercise physiology (e.g. beta blockers for hypertensive patients). This should be proven by a specific study.

Another limitation is that extreme altitudes well above 5,000 m were excluded. But this is of minor importance since the rating of perceived exertion is of very little practical use at such altitudes: Normally climbers who go there are physically fit, completely healthy and there is no altitude training here. On the other hand the increasing number of elderly people who do the trek to Everest base camp (5,364 m) or Annapurna Circuit (5,416 m) and who do this with several pre-existing diseases as it was shown by several studies (e.g. [24-27]) that it may be useful to check an altitude equivalent to about 6,000 m, which corresponds to the highest altitude of such treks plus a safety margin.

The study was performed with unacclimatized mountaineers only. This was done because there is no valid rating of acclimatization and some individuals may be "slow acclimatizers". Unacclimatized persons guaranteed the same physiological status for all participants and there is no evidence in literature that acclimatization has an effect on perceived exertion. At least during early stage of altitude exposure it only reduces the risk of altitude diseases. Ventilatory acclimatization occurs several days later (day 8 to 15) and not within the short exposure (some hours) of our collective [28, 29].

The fact, that we have investigated hypobaric hypoxia only is no limitation when persons are exposed to isobaric hypoxia up to ~10.5%, which corresponds to ~5,000 m [30], since the

differences in breathing mechanics by lower viscosity of the air in hypobaric conditions is – although statistically significant – clinically irrelevant at the altitudes investigated here [31-33]. However, this may be investigated in a future study and if conditions above ~6,500 m should be discussed, this effect of a different breathing mechanics should be taken into account.

One might be surprised that no relevant difference of the maximal workload at 3,000 m compared to sea level has been found. This should be an effect of the profile of the workload during ergometry: Exact data of minor differences may be found by a continuous increase of the load only ("ramp profile"), but not by the relatively large steps of +40 Watts for each level except if (questionable) interpolations would be used. With 1,000 m of altitude above 1,500 m a decrease of maximal aerobic performance of about 11.5% may be expected [5, 34-36]. Both, the workload given by such a procedure and the Borg scale are discrete variables which do not allow the exact determination of minor differences. We postulate that external (e.g. two discrete variables) and probably individual factors (e.g. form of the day) have superimposed the minor effect of altitude.

## Conclusion

The rating of perceived exertion by Borg's Scale is valid up to about 5,000 m and for healthy persons. It should be also valid for patients but this should be confirmed by a future study. The factor(s) which indicates strain to the body and which are rated (or rated most) by Borg's Scale should be evaluated in a specific study.

## Conflict of interest

Neither the grant nor the award (both strictly controlled by the scientific committees of the societies), nor the support by the industry mentioned in "acknowledgements" had any restrictions. Therefore all authors declare that there was no conflict of interest.

## Acknowledgements

The investigation was part of the research project "Demands on Rescuers at Alpine Accidents". The project was supported initially by the Austrian Society for Alpine and Altitude Medicine (ÖGAHM) and later awarded by the "E.W. Baader Award" of the German Society of Occupational and Environmental Medicine (DGAUM). Many thanks to Cosmed Germany, Siemens, Radiometer Copenhagen and Marquette-Hellige Medical Systems Germany who supported the study with loaned equipment. The authors wish to thank all participants for their voluntarily and enthusiastic contribution to the project.

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