

PREDICTION OF MAXIMAL ON-SIGHT PERFORMANCE DURING ROCK CLIMBING CAMP

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Abstract

The aim of this study was to use heart rate (HR) to predict maximal on-sight performance (MaxOS) during a 2-week climbing camp. Participants were six male intermediate-level sport rock climbers. Two weeks before the trip, the climbers performed maximal incremental tests on arm ergometer; the maximal HR ($HR_{\max\text{-arm}}$) and HR on lactate threshold ($HR_{LT\text{-arm}}$) were determined. Each climber provided written self-assessment of their OS level (Pre-MaxOS). Additionally, their age-predicted maximal heart rate ($HR_{\max\text{-formula}}$) was calculated. On the climbing day, the climber tried to complete 5 climbing routes. During climbing HR was constantly monitored and heart rate average (HR_{ave}) and peak (HR_{peak}) were assessed. After each climbing route the participants completed NASA Task Load Index test (NASA-TLX) and assessed a level of criticality for the purpose of analysis of perceived climbing workload. Data correlation trend line of the first two days of camp was chosen to predict MaxOS. The results demonstrate that Pre-MaxOS underestimated the real level of performance in 5 climbers (up to 1.5 Fr grade) while in one climber the level was overestimated (1 Fr grade). All climbing data comprised 299 lead climbs, 83% of which had been successfully completed. The best predictors of OS performance were HR_{peak} and $HR_{\max\text{-formula}}$.

Keywords: Heart rate monitoring; sport rock climbing; NASA-TLX; level of criticality

PRÉDICTION DU MEILLEUR RÉSULTAT D'ESCALADE DANS UN STYLE A VUE PENDANT L'ESCALADE DURANT UN CAMP D'ESCALADE

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Résumé

Le but de l'étude était d'utiliser la fréquence cardiaque (HR) dans la prédiction du meilleur résultat de l'escalade à vue (MaxOS) pendant un camp d'escalade de deux semaines. Les participants de la recherche étaient six grimpeurs de sports du niveau intermédiaire. Deux semaines avant le départ, les grimpeurs ont fait un test d'effort progressif à l'ergomètre en utilisant les bras. Le maximum HR ($HR_{\max\text{-arm}}$) et HR au seuil de lactate ($HR_{LT\text{-arm}}$) pendant le travail des bras ont été déterminés avec son aide. Les participants ont également donné leur opinion sur leur niveau d'escalade à vue (Pre-MaxOS). En outre, leur HR maximale a été calculée à partir de l'équation basée sur la dépendance de l'HR par rapport à l'âge ($HR_{\max\text{-formula}}$). Pendant la journée d'escalade, chaque participant a essayé d'enchaîner 5 voies d'escalade. Pendant l'escalade, HR a été surveillée en permanence, dont la moyenne HR (HR_{ave}) et son pic (HR_{peak}) ont été déterminés. Après avoir fini chaque grimpe, le participant a complété le test NASA TLX (NASA TLX) et il a déterminé le niveau de criticité pour analyser la pression perçue par lui durant l'escalade. Pour la prédiction du MaxOS nous avons utilisé la tendance des lignes de corrélation de données des deux premiers jours du camp. D'après les résultats obtenus nous avons constaté que 5 grimpeurs ont sous-estimé leur niveau de maîtrise (jusqu'à 1,5 degrés Fr) et 1 personne a surestimé ses capacités (1 degré Fr). Nous avons effectué 299 mesures, dont 83% ont été couronnées de succès. Parmi tous les paramètres, HR_{peak} et $HR_{\max\text{-formula}}$ constituaient les meilleurs prédicateurs du résultat de l'escalade à vue.

Mots-clés: Surveillance de la fréquence cardiaque, escalade sportive, NASA-TLX, niveau de criticité

Introduction

Heart rate (HR) monitors have become a common training tool in sports. It has been established that HR and workload, oxygen uptake (VO_2) and energy expenditure (EE) are linearly related over a wide range of submaximal intensities (Achten & Jeukendrup, 2003). These relationships are used to predict, estimate and monitor an individual fitness level (e.g. $\text{VO}_{2\text{max}}$). HR is easy to monitor, shows a very stable pattern during exercise; HR data can be used to adjust the intensity of a work bout if necessary (Bompa & Haff, 2009). HR can also be applied to control fatigue and avoid overtraining. Another development in HR monitoring is the measurement of heart rate variability (HRV) that may have various applications in sport (Aubert et al., 2003). This study was undertaken to use HR to predict maximal climbing performance during a climbing camp.

Methods

Subjects: The study comprised six male sport rock climbers (age 26 ± 2.58 years, body height 1.77 ± 0.05 m, body weight 76.8 ± 6.83 kg, body fat $12.9 \pm 3.65\%$, $\text{VO}_{2\text{ max-arm}}$ 43 ± 8.43 ml/min/kg). All subjects were intermediate-level (6a - 7a OS) and had short climbing experience (1-3 years). The study was approved by the Institutional Ethics Committee (No. 10/2014).

Research design: The study was intended to predict on-sight level of participants (OS, i.e. climbing with no beta or prior knowledge of the route) obtained during a 14-day climbing camp in Orpierre in the south of France. On the climbing day, the study participants would spend approximately 6 hours in the rock climbing area trying to complete 5 climbing routes. Polar V800 (Polar Electro OY, Kempele, Finland) was used to monitor HR during each climb and heart rate average (HR_{ave}) and peak (HR_{peak}) were assessed. After each climb the participants completed NASA Task Load Index (NASA-TLX) questionnaire for the purpose of analysis of perceived climbing workload (Biernacki et al., 2007). Additionally, a 10-point level of criticality score ("What level of your maximal performance was used to climb this route?") was used to determine climbing difficulty (Carlstedt, 2013). Data of the 2-day adaptation phase of camp were chosen to predict the best individual climbing performance ultimately achieved in peak performance phase in the second week of the camp (MaxOS). The grade of the climbing route was converted from French scale (Fr) to a decimal scale (Decimal) (Köstermeyer, 2000) and was presented as a percentage of a climber's maximum OS level (%). Two weeks before the trip, the climbers performed maximal incremental tests on arm ergometer and provided written self-assessment of their OS level (Pre-MaxOS). The results of the incremental test revealed maximal oxygen uptake ($\text{VO}_{2\text{ max-arm}}$), maximal heart rate ($\text{HR}_{\text{max-arm}}$) and heart rate on lactate threshold ($\text{HR}_{\text{LT-arm}}$) during arm work. Age-predicted maximal heart rate ($\text{HR}_{\text{max-formula}}$) equation by Tanaka et al. (2001), i.e., $208 - 0.7 \times \text{age}$, was also used.

Data analysis: Pearson correlation (r) was used for statistical analysis; the level of significance was set at $p < 0.05$. Data were cleaned of outliers (outcomes far from $\pm 95\%$ confidence limits or obtained from too easy climbing routes). Correlation trend line was plotted between climbing difficulty and independent variables. An intersection between trend line and maximal values of the independent variables was considered climbing difficulty. The difference between this estimate and real MaxOS was defined as prediction error. If the error was less or equal a half of climbing difficulty grade, the variable was considered a strong MaxOS predictor. The data analysis tool was STATISTICA 13.0 (StatSoft Poland).

Results & Discussion

Of the 14 camp days 10 were climbing days and 4 were rest days. Over the 10 climbing days, each climber led 50 ± 1 climbing routes. All climbing data comprised 299 lead climbs, 83% of which had been successfully completed. The participants' peak preparedness was noted on days 11 and 13 while climbing the hardest routes OS.

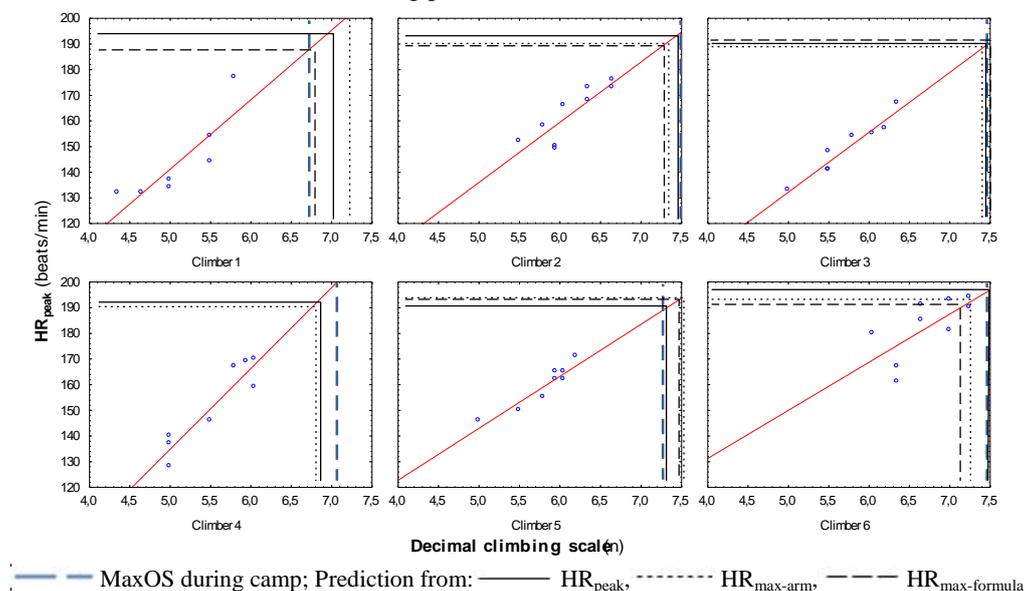
Table 1. Differences between the best climbing OS performance and prediction of OS grade based on the other variables measured during the camp

	Climber 1		Climber 2		Climber 3		Climber 4		Climber 5		Climber 6	
	Decimal	Fr	Decimal	Fr	Decimal	Fr	Decimal	Fr	Decimal	Fr	Decimal	Fr
Pre-MaxOS	-0.65	-1.5	-0.1	-0.25*	-0.45	-1	-0.15	-0.25*	-0.4	-0.75	0.5	1
HR_{ave}	-0.05	0*	0	0*	-0.6	-1.25	0	0*	-0.2	-0.5*	0.35	0.5*
HR_{LT-arm}	1.1	2	-0.55	-1.5	0.4	1	0	0*	-0.3	-0.5*	-0.65	-1.25
HR_{max-formula}	0.05	0*	-0.2	-0.5*	0.05	0*	-0.2	-0.25*	0.1	0.25*	-0.3	-0.5*
HR_{max-arm}	0.55	1	-0.15	-0.5*	-0.05	0*	-0.2	-0.25*	0.15	0.25*	-0.25	-0.5*
HR_{peak}	0.3	0.5*	0	0*	0	0*	-0.2	-0.25*	0	0*	0	0*
Level of criticality	0.55	1	0.45	1	1.5	3	0.55	1.25	1.5	3	-0.15	-0.25*
TLX-NASA score	1.35	2.5	0.85	1.75	1.5	3	0.4	0.75	1.25	2.5	0.65	1.25

Pre-MaxOS - the best on-sight climbing performance before the camp, HR_{ave} and HR_{peak} - average and peak heart rate during climbing, HR_{max-arm} and HR_{LT-arm} - heart rate maximal and on lactate threshold during arm incremental test, HR_{max-formula} - age-predicted maximal heart rate, Decimal and Fr - decimal and French climbing scale.

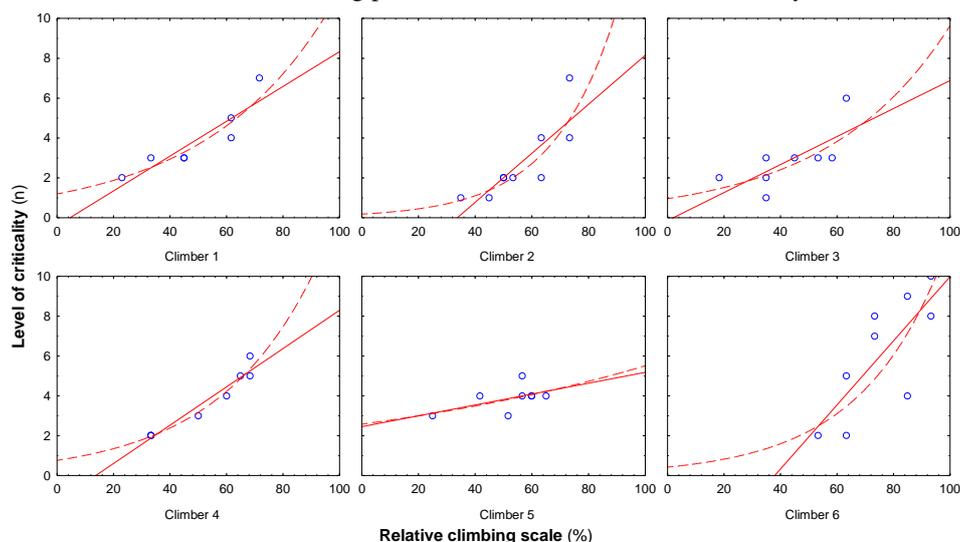
* - strong predictor: Error $\leq \pm 0.5$ Fr grade

Figure 1. Predictions of the best OS climbing performance based on maximal HR of the first two camp days



Each climber exhibited a statistically significant correlation between each of HR indexes and climbing difficulty (r Pearson: HR_{ave}: 0.70 - 0.92; HR_{peak}: 0.68 - 0.96). A statistically significant correlation was also revealed between climbing difficulty and the level of criticality ($r = 0.63$ to 0.97) and TLX-NASA score ($r = 0.64$ to 0.98). The results of prediction are shown in Table 1. The best predictors of OS performance were HR_{peak} and HR_{max-formula} (100% accuracy) followed by HR_{ave} and HR_{max-arm} (83% accuracy) (Fig. 1). Pre-MaxOS accurately predicted performance of 2 climbers only; it underestimated 3 climbers (from 0.7 to 1.5 Fr grade) and overestimated one climber. The linear trend correlation lines of subjective variables were weak predictors of MaxOS: level of criticality (17% accuracy) and TLX-NASA (0% accuracy) (Fig. 2).

Figure 2. Predictions of the best OS climbing performance based on level of criticality of the first two camp days



Both for coaches and athletes is important to know the actual climbing fitness and the way to predict the best performance during a rock climbing camp. In this study the level of performance was underestimated in 5 climbers (up to 1.5 Fr grade) and overestimated in one climber when based on the participants' self-assessment before the trip. However, it was possible to precisely (Error up to 0.5 Fr grade) determine the OS level of each climber in the adaptation phase of the camp. After two climbing days, the best predictors of climbing performance were HR_{peak} and $HR_{max-formula}$. Peak HR values turned out a better predictor than average HR since mean values depended on baseline measurements and slight latency of heart rate response to an increase in muscle work (Magiera et al., 2018). The best OS level cannot be easily predicted based on the subjective measurements (level of criticality and TLX-NASA). A possible explanation could be the nonlinearity of these relationships (Fig. 2) and the fact of climbers being unable to accurately rate easy tasks (Delignières et al., 1993).

As mentioned above, HR monitoring is widely used in sport. However, HR tends to vary under the influence of a number of factors (physiological, mental, behavioural and environmental) (Achten & Jeukendrup, 2003, Valentini & Parati, 2009). The use of HR as a climbing intensity indicator continues to raise controversies among researchers because the linear relationship between HR and VO_2 can be disturbed in climbing (Michailov, 2014; Sheel et al., 2003). Heart rate is disproportionately high to oxygen consumption which is accounted for by sustained isometric contractions that hinder the local blood flow, the arms being repeatedly held above the heart level, the muscle metaboreflex, and reliance on both aerobic and anaerobic energy systems (Michailov, 2014). It is therefore difficult to determine energy expenditure based on HR only. Despite the above mentioned limitations and inadequacies, HR is a good indicator of overall stress and organism arousal (Achten & Jeukendrup, 2003). The main cause of success or failure during climbing lies with the climber and their fitness, fatigue, emotional state, etc. (changes in internal load, overall stress) as rock climbing route remains unchangeable (i.e. the external load is constant).

The limitation of this investigation was a small number of male intermediate-level climbers. A study including a great number of participants showed three different patterns of the heart rate performance curve (HRPC) approaching maximal power output, and namely regular (with deflection point), strictly linear and inverted curves (Hofmann & Pokan, 2010). The inverted curves occur sporadically in performance prediction (e.g., 6-8 % of subjects). A regular curve is much more frequent and it might slightly underestimate climbing performance.

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