Original Article

Effects of a 6-week additional work on performance capacity: Hints for a parasympathic overtraining?

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ABSTRACT

Introduction. Maximum performance can only be achieved with an optimal balance of training and recovery. Already 15 years ago Jeukendrup & Hesselink (1994) mentioned that hints can be derived from lactate curves concerning a potential overreaching. In this small study we show the effects of a six-week standard infantry military training on performance capacity in young elite orienteers. The potentially induced overreaching and the ingoing alterations of heart rate patterns and lactate answers shall be analysed. Material & Methods. Five young elite orienteers (22.6 ± 0.52 years / 178.4 ± 7.6 cm / 66.4 ± 3.4 kg) completed an exhaustive treadmill test, first at one and a half year before, second at half a year before and third immediately after completing a six-week period of a session of a hard infantry military training. Results. After the six-week additional military training measurements of heart rate decreased at speed 10.8 km/h from 142.6 ± 11.6 to 129.2 ± 11.9 (p = .0192); at speed 12.6 km/h from 153.4 ± 11.4 to 141.2 ± 12.6 (p = .0192); at speed 14.4 km/h from 166.4 ± 10 to 155.4 ± 12.2 (p = .02); at speed 16.2 km/h from 177.4 ± 6.9 to 168.4 ± 6.5 (p = .0244); at speed 18 km/h from 186.2 ± 5.8 to 181.4 ± 3.6 (p = .0313) compared to the measurement half a year earlier. Discussion. We strongly believe that these lower average heart rates for submaximal speed stages cannot be assessed as positive in terms of performance but might be in accordance with a parasympathetic overreaching respectively parasympathetic stimulation. The increased parasympathetic tone probably required a correspondingly stronger sympathetic stimulus for activation, which, however, could not act as efficiently as after normal training conditions as athletes were not rested well yielding to a shift of the heart rate/performance curve in line with findings of Jeukendrup & Hesselink (1994) of lactate curve in cyclists already 15 years ago.
Keywords: Overtraining; Overreaching; Heart rate; Lactate; Performance.

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INTRODUCTION

Elite athletes struggle to achieve balance between training too much or not enough. Too much training is associated with a state called overreaching, with its possible detrimental effects on competition and training. Overreaching is characterized by an unplanned and unexpected drop in performance despite increased or maintained training load (Vogel, 2001). Overreaching is the result of a long-term imbalance between stressors and factors of recovery (Vogel, 2001). Untreated Overreaching may lead to Overtraining Syndrome, whereby overtraining is a symptom complex with disease value (Vogel, 2001; Kreider, Fry & O'Toole, 1997; Hooper, Mackinnon, Gordon, Bachmann, 1993). So far, unfortunately clear definitions and criteria of overreaching and overtraining are missed (Vogel, 2001). In consequence, many different causes are described that can shift the balance between strain and relaxation and thus lead to overreaching and/or even overtraining (Vogel, 2001). Overreaching seems a very common problem in endurance sports such as triathlon, duathlon or running, whereby Jeukendrup & Hesselink (1994) already 15 years ago mentioned to carefully analyse lactate curves in performance tests to detect a potential overreaching. Career prevalence of close to two-thirds are described (Morgan et al. 1987; Morgan et al. 1988; Vogel et al. 2001). Evidence exists, that recovery from overreaching may take two to three weeks, however clear definitions are not reported (Vogel, 2001; Kuipers et al. 1988; Hooper & Mackinnon, 1995; Urhausen & Kindermann, 2002). From a pathophysiological mechanism, often a sympathetic and a parasympathetic overreaching respectively overtraining are reported (Vogel, 2001; Hooper & Mackinnon, 1995; Urhausen & Kindermann, 2002; Israel, 1958). However, many other descriptions of different mechanisms exist (Vogel, 2001; Hooper & Mackinnon, 1995; Urhausen & Kindermann, 2002; Israel, 1958). In reality, it is often a diagnosis of exclusion in the case of a drop in performance that lasts for at least about two weeks despite rest and recovery without a verifiable organic pathological cause (Urhausen & Kindermann, 2002). Different stressors are described in consequence yielding to a pathological state (Vogel, 2001; Vogel et al. 2001) Changes in setting, such as new living areas and other challenges in the personal life are described as possible causative factors (Vogel, 2001; Vogel et al. 2001). Demands, on young athletes, are particularly high when setting changes occur. If the risk of overtraining at home in the usual setting is low, it becomes more pronounced when new stressors are introduced. This is particularly the case when young high-performance athletes are confronted with other strain such as an intensive time at work or military service and education over a longer period. Especially in such situations, when existing routines are abandoned and the regeneration routines may no longer work as well as previously, performance can be adversely affected and there might be an increased risk of overreaching. This leads directly to the aim of this study: To what extent a change in daily activity and setting have an effect on physical performance. As negative hypothesis would be that a 6-week basic military training does not affect performance (Popper, 1969).

MATERIAL & METHODS

Participants

Five young male competitive athletes (22.6 ± 0.52 years / 178.4 ± 7.6 cm / 66.4 ± 3.4 kg) of the high-performance range respectively member of the national orienteering team or qualified for international competitions.

Procedures

The sample completed a standardized form of a treadmill test to exhaustion around one and a half year before, half a year before and immediately after a standard infantry military training. The military training endured 6 weeks and consisted of basic infantry military training. During this time athlete tried to train in addition to the standard training for themselves in the evening and competed at races during the weekend.

Treadmill test to exhaustion started at 10.8 km/h and speed was increased by 1.8 km/h per stage, whereby lactate, heart rate and Borg scale (6-20) were measured at each speed level (Wehrlin, Held, Marti, 2001; Borg, 1998). Measurements of lactate were performed with "*Laktat Pro*" (Arkray Inc., Japan) and heart rates with "*Accurex*" (Polar Electro, Finland). Measurements were conducted in accordance with general guidelines at the time of measurement in line with local regulatory practice. The study was approved and conducted in line with the ethical requirements of the internal institutional Review Board.

Statistical analysis

Descriptive statistics for all stages of the treadmill test were calculated with calculation of the mean values and standard deviations for heart rate, lactate and BORG scale. Furthermore, heart rate and lactate were plotted against speed. Paired two-sided t-tests were calculated to test for significant differences in heart rate, lactate, BORG-Scale for the measurement after the additional stress versus one and a half year before and for measurement half a year before versus one and a half year before the additional stress. Significance level were adjusted by Benjamini & Hochberg correction for multiple comparison (Benjamini & Hochberg, 1995). Furthermore, the average increase of heart rate per minute was calculated between two speed levels for the three measurements. Calculations were performed using Microsoft Excel (Microsoft Inc., Redmond, Washington, USA) and Graphpad Prism (GraphPad Software, Inc., La Jolla, California, USA).

RESULTS

Figure one and Table one show the results of the treadmill test to exhaustion. No significant difference can be detected for heart rate, lactate and BORG-Scale between the two tests one and a half year in advance and half a year in advance. However, on the tests immediately following the six weeks of military training, significant decrease in average heart rate were detected at 10.8km/h ,12.6km/h, 14.4km/h, 16.2 km/h and at 18km/h compared to the measurement half a year earlier (Figure 1a). Interestingly, lactate concentrations were not significantly different after military training versus half a year prior (Figure 1b).

Regarding the exhaustive element respectively the maximum heart rate achieved in the treadmill test, it can be mentioned, that no significant difference could be detected for heart rate max with 195 ± 6.5 beats per minute one and a half year in advance to 197 ± 3.7 beats per minute ($p = .321$) half a year in advance. In addition, no significant difference was detected half a year in advance with 197 ± 3.7 beats per minute versus after the military training with 197.2 ± 5.8 beats per minute ($p = .942$). Regarding the maximum speed, it can be mentioned, that no significant difference could be detected for maximum speed with 20.04 ± 0.8 one and a half year in advance versus 20.1 ± 0.8 km/h ($p = .587$) half a year in advance. Furthermore, the decrease in speed max half a year in advance with 20.1 ± 0.8 km/h versus post infantry training with 19.8 ± 0.5 km/h was in addition not significant ($p = .20$).

Concerning the average increase from one speed level to the next (e.g. 10.8 km/h to 12.6 km/h, 12.6 km/h to 14.4 km/h, 14.4km/h to 16.2 km/h, 16.2 km/h to 18 km/h, 18km/h to 19.6 km/h) it is to mention that one and a half year before exposition 12.4 ± 1.5 heart beats per minute were detected, which significantly decreased to 10.2 ± 2.2 beats per minute half a year before exposition ($p = .008$). This finding of a lower increase of average heart rate in the sample seemed reversible with 11.82 ± 1.1 beats per minute after the additional training ($p = .034$).

Table 1. Results of the treadmill tests for the three measurement times (one and a half year before intervention, half a year before intervention and immediately after the intervention.

	After military training Heart rate (Mean±SD)	**p-Value**	**Half a year in advance Heart rate (Mean±SD)**	**p-Value**	**One and a half year in advance Heart rate (Mean±SD)**
10.8 km/h	129.2 ± 11.9	.0192*	142.6 ± 11.6	.7967	139.4 ± 12.3
12.6 km/h	141.2 ± 12.6	.0192*	153.4 ± 11.4	.9181	152.6 ± 13
14.4 km/h	155.4 ± 12.2	.02*	166.4 ± 10	.7967	164.8 ± 9.9
16.2 km/h	168.4 ± 6.5	.0244*	177.4 ± 6.9	.9181	177.2 ± 7.7
18 km/h	181.4 ± 3.6	.0313*	186.2 ± 5.8	.7967	187.8 ± 5.6
19.8 km/h	191.7 ± 4	.724	193.5 ± 3.4	.7134	198.5 ± 5.5
Speed max*	19.8 ± 0.5	n/a	20.1 ± 0.8	n/a	20.04 ± 0.8
	Lactate (Mean±SD)	**p-Value**	**Lactate (Mean±SD)**	**p-Value**	**Lactate (Mean±SD)**
10.8 km/h	0.9 ± 0.2	.1224	1.2 ± 0.2	.8826	1 ± 0.1
12.6 km/h	0.9 ± 0.2	.1224	1.4 ± 0.2	.8826	1 ± 0.2
14.4 km/h	1.4 ± 0.6	.4694	1.7 ± 0.3	.8826	1.4 ± 0.2
16.2 km/h	2.3 ± 0.8	.655	2.6 ± 0.5	.8826	2.1 ± 0.4
18 km/h	4.4 ± 1.2	.6726	4.3 ± 0.8	.8826	4 ± 0.9
19.8 km/h	6.9 ± 2.4	.655	7.3 ± 2.3	.8826	7.1 ± 2.2
Speed max *	8.7 ± 0.8	n/a	9.2 ± 2	n/a	9.7 ± 1.3
	BORG (Mean±SD)	**p-Value**	**BORG (Mean±SD)**	**p-Value**	**BORG (Mean±SD)**
10.8 km/h	10.4 ± 0.9	.6339	9.6 ± 0.9	.423	8.6 ± 1.1
12.6 km/h	11.6 ± 0.5	.6339	11.4 ± 0.5	.7478	11.4 ± 0.9
14.4 km/h	13 ± 0.7	.99	13 ± 0.7	.932	13 ± 0.7
16.2 km/h	14.6 ± 0.5	.99	14.6 ± 0.9	.7478	14.8 ± 1.1
18 km/h	16.8 ± 0.4	.6339	16.6 ± 0.9	.99	16.8 ± 0.8
19.8 km/h	18.7 ± 0.6	.6339	19 ± 0.1	.99	19 ± 0.8

*Note. * Speed max was different for the three measurements with 20.04 ± 0.8 one and a half year in advance versus 20.1 ± 0.8 km/h half a year in advance versus 19.8 ± 0.5 km/h after the military training.*

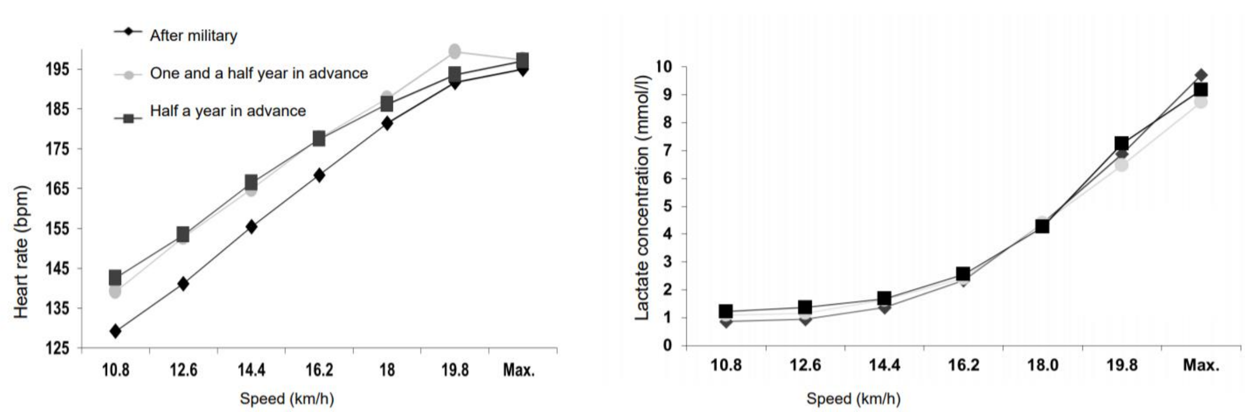

Figure 1. Heart rate and lactate concentrations in the treadmill test.

DISCUSSION

The aim of this study was to analyse effects of a 6-week additional strain on performance. It was postulated with negative hypothesis that there would be no effect from an additional 6-week military infantry training. Strong evidence of changes in treadmill tests due to overtraining exist.(Vogel, 2001; Vogel et al. 2001; Tschopp et al. 2001). One of the core results in this multiple-case analysis would be a detected decline in maximum speed, however this is probably due to small sample not significant (p = .2). Such an alteration would be in line with the criteria set by Uusitalo et al. 2000, which directly mention a reduced maximum speed in the treadmill test as sign of overreaching. Others describe various potential criteria for overreaching (Tschopp et al. 2001). (i) A decrease in the maximum speed in the lactate step test on the treadmill (by 0.6 km/h or by 10%) (ii) A decrease in the lactate concentration in a treadmill test by 1.0 mmol/l or by 20% on the last stage that was fully completed (iii) A change in the heart rate in a treadmill test by an average of 10 bpm per stage or more. Using all these criteria, it becomes obvious that they are only partly met. We found only a decrease of 0.3 km/h and almost no change in lactate concentrations. However, changes of heart rate did reach criteria. The lower average heart rates at sub maximum speeds might be due to overreaching. Israel already mentions a heart rate change of more than ± 4 bpm as suspicious. For overreaching often decreased heart rates are described, which would be in line with our findings (Vogel, 2001; Vogel et al. 2001; Wassiljewa, et al. 1955). Interestingly, especially the heart rate alterations between to speed levels was different after the intervention implying an irregularity of vagal tone. In detail, after the intervention in the treadmill test the average increase per speed stage was significantly higher, which might be interpreted as a protective mechanism of the human body. The parasympathetic tone might have been increased; a correspondingly stronger sympathetic stimulus was needed for activation. This would be in line with descriptions that fatigue causes a protective inhibition implying a stronger stimulus is necessary for activation (Vogel, 2001; Vogel et al. 2001; Hedelin et al. 2000; Mateeff, 1957; Wassiljewa, 1955). These hints refer primarily to Pavlov's research, according to which with increasing stimulus reaction increases (Vogel, 2001; Vogel et al. 2001; Hedelin et al. 2000; Mateeff, 1957; Wassiljewa, 1955). From an evolutionary point of view, this would make sense as a protective mechanism (Dobzhansky, 1973). The question has to be addresses why potential overtraining respectively more strain is necessary for sympathetic activation? As the great Theodosius Dobzhansky famously wrote more than 40 years ago, "*nothing in biology makes sense except in the light of evolution*" the argument comes up that a stronger stimulus is necessary for activation which can be interpreted as a protection mechanism to not being activated to early and sufficient rest is guaranteed. Interestingly, results show, that when really needed body is still able to highly perform. This was probably very important as an answer to a thread in evolution respectively to start a fight or flight answer. Limits of activation and realization of full potential exist, as not rested and in consequence not optimally recovered only a share of the potential can be realized in line with our findings of a lower maximum speed after the additional strain.

Practical implications

A down-shift of the heart rate/performance curve for submaximal performances can be taken as hint of a potential overreaching.

However, in practice often a clear diagnosis can first be made after decreasing training load and restored performance.

These cases serve as a reminder to interpret heart rate and lactate curves carefully especially together with complaints such as deteriorating performance and subjective complaints of irritability.

AUTHOR CONTRIBUTIONS

BG, RV and JW designed the study. RV performed measurement. BG and RV performed analysis. RV concepted the manuscript draft. BG made final changes. RV and BG are shared first authors. All authors read final version and agreed for publication.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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