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Exercise Intensity of Cycle-Touring Events

Abstract

The aim of the study was to analyze the exercise intensity of recreational cyclists participating in a cycling-touring event. In 14 male healthy recreational cyclists heart rate (HR) monitoring was performed during the Ötztal Radmarathon 1999 (distance: 230 km; altitude difference: 5500 m) in order to evaluate the HR response and to estimate the cardiopulmonary strains for the less-trained athlete confronted with such a marathon. Four different exercise intensities were defined as percentages of maximal HR (HR_{max}) as follows: recovery HR (HR_{re}) < 70% of HR_{max}; moderate aerobic HR (HR_{ma}) = 70 – 80%; intense aerobic HR (HR_{ia}) = 80 – 90%; and anaerobic HR (HR_{an}) > 90%.
All athletes finished the competition successfully. The mean racing time was 10 h 14 min, the average speed 22.5 km/h. The mean HR_{max} was 188 bpm, the average value of the measured HRs ($HR_{average}$) was 145 bpm resulting in a mean $HR_{average}/HR_{max}$ ratio of 0.77. Athletes spent 18.5% (1 h 54 min) of total race time within HR_{re}, 28% (2 h 52 min) within HR_{ma}, 39.5% (4 h 02 min) within HR_{ia}, and 14% (1 h 26 min) within HR_{an}. The vast majority of exercise was done under "aerobic conditions" ($HR_{re} + HR_{ma} + HR_{ia}$ = 86% or 8 h 48 min) – confirming the knowledge that the aerobic energy supply is crucial for the performance of long-term exercise. The large amount of high exercise intensities ($HR_{ia} + HR_{an}$ = 53.5% or 5 h 30 min), however, features the intense cardiopulmonary strains evoked by such competitions. The HR response was related to the course profile with HRs significantly declining in all subjects to an extent of 10% during the course of race.
Our findings show that the exercise intensity borne by recreational cyclists during a cycle-touring event is high and very similar to that of professionals. With respect to the high cardiovascular strains a thorough medical screening is advisable for any participant of such an event combining both high volume and high intensity loads.

Key words
Heart rate · exercise intensity · long-term exercise · recreational cycling

Introduction

Man's physiological heart rate (HR) response to long-term cycling is mainly based on data gained from professional road cycling [8,15,20,21]. Corresponding information about the less-trained, occasionally active athlete, i. e. the recreational or hobby cyclist, undergoing analogous strains is lacking. With increasing participation of heterogeneously trained athletes in more and more grueling ultraendurance racing events, a clear delineation of the cardiovascular demands becomes essential for the quantification of exercise intensity as well as for the estimation of potential health hazards.

The intensity of a specific exercise can be estimated by the HR response [3,10,11]. As there is a fairly linear relationship between exercise intensity (oxygen consumption) and HR, HR monitoring

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has become an established means for exercise physiologists, coaches, and athletes to describe exercise and training intensities [2,13]. Regular aerobic training reduces the submaximal HR at a definite absolute workload but leaves the maximal HR (HR_{max}) relatively unaltered regardless of training status in a given population [1,14,25]. The American College of Sports Medicine (ACSM) therefore recommends exercise intensities to be prescribed within a range of 60–90% of HR_{max} depending on the individual performance capacity [1].

In the laboratory setting several studies investigated various cardiovascular parameters of both amateur and professional cyclists [4–7,12,16]. In the field setting, however, only a few studies were done to survey the human HR response with most of them performed on professionals only [8,15,20,21]. To our knowledge there are no corresponding data quantifying the exercise intensity of the less-trained, recreational athlete competing in strenuous marathon cycling. We therefore performed this study.

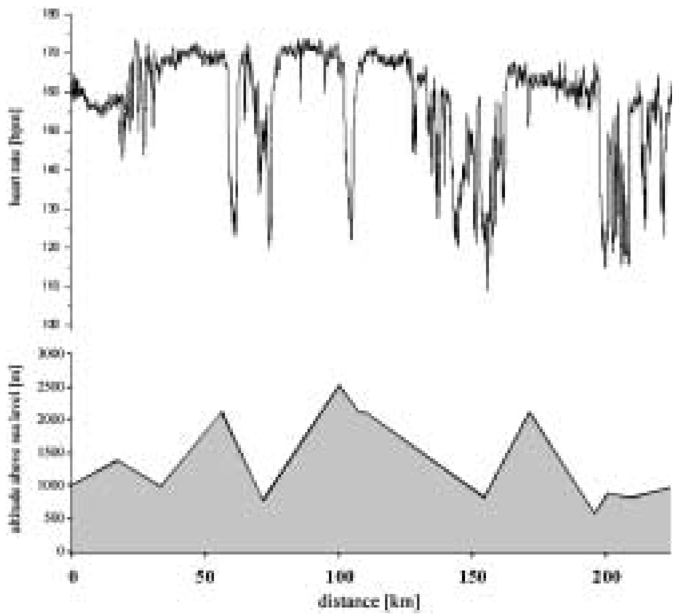

Fig. **1** Individual heart rate data example during the Ötztal Radmarathon. Heart rate profile (top); Course profile (bottom).

Materials and Methods

Subjects

Fourteen volunteers out of 1420 participants of the Ötztaler Radmarathon held on August 29th, 1999 in Tyrol were subjects of the study. All of them were experienced recreational cyclists, well prepared for the race. They were considered to be healthy according to case history and prior clinical and laboratory examinations. Subjects provided written informed consent in accordance with guidelines established by the Institutional Ethics Committee.

Characteristics of the race

The Ötztaler Radmarathon is a 1-day cycling race with extraordinary efforts and belongs to the category of "Cycle-Touring Event" of the Union Cycliste Internationale (UCI). The race is held every year in the Tyrolean Alps. Its total distance is 230 km at an altitude of 550–2500 m above sea level. The cumulative altitude difference is 5500 m, including 4 mountain passes: Brennerpass (1374 m), Jaufenpass (2097 m), Timmelsjoch (2509 m) and the Kühtai (2097 m) (Fig. **1**). The workload of the race is certainly comparable to that of the hardest mountain stages of professional cycling. The race took place under dry and fine weather conditions. During the race, temperatures ranged from 14–21 °C, and humidity from 55–85%.

Heart rate monitoring

HRs were recorded during the whole marathon by the use of Polar Vantage NV telemeters (Polar Electro Oy, Finland). All study participants were familiar with the use of these HR monitors. The recorded data were analyzed by using a computer program (Polar Heart Rate Analysis Software 5.03, Polar Electro Oy, Finland) which allows the user to select 3 reference HRs and to establish 4 levels of exercise intensity. The reference HRs were calculated by multiplying HR_{max} by the factors 0.7, 0.8, and 0.9 [1]. HR_{max} was obtained from each athlete by pre-race maximal exercise testing. All athletes were used to training under the control of HR monitoring and well informed about their HR_{max}. The 4 exercise intensities were classified as follows: recovery heart rate (HR_{re}) < 70% of HR_{max}; moderate aerobic heart rate (HR_{ma}) = 70–80%; intense aerobic heart rate (HR_{ia}) = 80–90%; anaerobic heart rate (HR_{an}) > 90%. This implementation of different HR ranges allowed absolute and relative subdivision of total race time into 4 levels of exercise intensity.

Biochemical markers

In addition to HR monitoring selected biochemical markers, e.g. haematocrit, haemoglobin and cardiac troponin I (cTnI), were determined by the means of standard methods as described previously [17,18]. Blood specimens were taken by venopuncture of a cubital vein the day before, immediately after and one day after the competition and analysed the same day. The venopuncture was done in lying position at the same time in the morning on the day before and after the race. On the day of competition it was performed in the afternoon immediately after the individual finish.

Statistics

Results are expressed as mean values ± standard deviation (SD). Correlations between the different HR responses and the athletes' baseline characteristics were calculated by simple linear regression analyses and were described by the correlation coefficient r by using the SPSS software package (version 9.0; Chicago, IL, USA). The Mann-Whitney test was used for the comparison of HR response in the differently fast subgroups and for the comparison of HR response, baseline characteristics and race results between athletes with and without exercise-induced cTnI levels. Statistical significance was assumed at a level of $p < 0.05$.

Results

Athletes' baseline characteristics and biochemical markers

All 14 athletes finished the ultramarathon successfully. Most of them were able to fulfill their personal expectations. The athletes investigated were representative of the average participant with respect to age and race time and well comparable to a larger athletic population regarding the baseline characteristics [18]. The mean racing time was 10 h 14 min, the average speed 22.5 km/h. The athletes' baseline characteristics and race results are given in Table **1**, some of the selected biochemical markers investigated in Table **2**.

Heart rate response

The HR response registered in the study was strongly related to the course profile (Fig. **1**). HR_{re} were mainly measured during the downhills of the passes, HR_{ma} during the flat sections of the course and the more intense HRs ($HR_{ia} + HR_{an}$) during the long-lasting ascents of the 4 passes of which three would be classified as "first category" and "hors categorie" within the Tour de France. During the course of the race a marked shift in the HR response towards lower rates was observed in all athletes. HRs declined significantly by an extent of about 10 %. The mean values of the athletes' HR_{max} and the average HR ($HR_{average}$) measured during the race were 188 and 145 bpm respectively, resulting in a mean $HR_{average}/HR_{max}$ ratio of 0.77. The times exercised by the cyclists at the 4 levels of intensity are illustrated in Table **3**. The mean time spent in the aerobic range ($HR_{re} + HR_{ma} + HR_{ia}$) was 8 h 48 min ± 52 min (86 ± 9.9 % of total race time) with the classical aerobic range ($HR_{ma} + HR_{ia}$) amounting to 6 h 54 min ± 34 min (67.4 ± 8.2 %). There was a correlation between the race time and the percentage of HR_{an} ($r = -0.73$; $p = 0.006$) but none for HR_{re}, HR_{ma}, HR_{ia}, respectively. Neither did we find a correlation between the HR response and the training state (i. e. cycled training-km in 1999) nor the other baseline characteristics of the athletes. Compared with slower competitors (race time > average race time of 10 h 14 min; n = 7), faster athletes (race time < 10 h 14 min; n = 7) had an enhanced $HR_{average}/HR_{max}$ ratio of 0.79 versus 0.75 and increased percentages of HR_{ia} and HR_{an} of 45.2 and 18.2 % versus 33.8 and 10 %. The absolute time proportion of exercise intensities in the total group and in these differently fast subgroups is illustrated in Fig. **2**.

Table **1** Athletes' baseline characteristics and race results

	Mean value	*SD*	*Range*
Age (yr)	36	6	28 – 45
Height (cm)	178.8	9.7	164 – 199
Body mass (kg)	75.0	7.9	60.9 – 88.6
BMI (kg/m^2)	23.7	1.5	21.7 – 27.5
Training-km in 1999	6591	2793	3300 – 12 000
Weekly training volume (km)	310	110	155 – 470
Years of practice	12	2	5 – 21
Race time (h/min)	10 h 14 min	35 min	8 h 33 min – 11 h 04 min
Average speed (km/h)	22.5	1.3	26.9 – 20.8
Weight loss (kg)	– 1.7	0.9	– 3.1 – + 1.0
Fluid intake (L)	5.1	1.2	3 – 7

BMI = body mass index; SD = standard deviation

Table **2** Biochemical parameters

	Pre-race	*Post-race*	*24 h after*
CTnI (> 0.5 µg/L)‡	0/14	5/14 (36 %)	3/14 (21 %)
Hct (0.4 – 0.52)	0.44	0.44^{NS}	0.41*
Hb (13.3 – 17.7 g/dL) (SD)	14.9 (0.8)	15.1 (0.8)^{NS}	13.9 (0.8)*
%ΔPV		– 2.2^{NS}	+ 10.8 †

CTnI = cardiac troponin I, Hct = haematocrit, Hb = haemoglobin
%ΔPV = percentage change in plasma volume, SD = standard deviation
* p < 0.00 (Wilcoxn signed-rank test), † p < 0.001 (one sample t test), NS = non significant
‡ values presented as number of positive observations/total observations

Table **3** Distribution of exercise intensity in percentage (%) and absolute time (h/min) of total race time

	HR_{re}	*HR_{ma}*	*HR_{ia}*	*HR_{an}*
Mean value	18.5 (1 h 54 min)	28 (2 h 52 min)	39.5 (4 h 02 min)	14.0 (1 h 26 min)
SD	9.6 (59 min)	12.3 (1 h 15 min)	15 (1 h 32 min)	10.7 (1 h 06 min)

HR_{re} < 70 % HR_{max}; HR_{ma} = 70 – 80 % HR_{max}; HR_{ia} = 80 – 90 % HR_{max}; HR_{an} > 90 % HR_{max}; SD = standard deviation

Discussion

Our study is the first to evaluate the HR response of recreational cyclists participating in a cycle-touring event. These events, many of which are yearly held in the European Alps and Pyrenees, enjoy growing popularity with increasing attendance. The findings demonstrate that the cardiovascular strains incident thereto are very high and that, despite a clearly lower performance capacity, recreational cyclists are able to undergo an exercise intensity comparable to that of professionals. Professional road cycling is a prime example for extreme endurance sport and of course physiologically very demanding. In the course of a single year professional cyclists cover distances of up to 35 000 km in their training and competitions which range from 1-day races to 21-day tours whose stage distances are from 5 to 300 km. Studies on the cardiovascular demands of professional cycling have consistently revealed that the exercise intensity decreases as follows: time trials > high mountain stages ("hors categorie") > flat stages [8,15,20,21]. Padilla et al. observed that world-class cyclists are capable to bear intensities of 85 – 89 % of HR_{max} (mean $HR_{average}/HR_{max}$ = 0.85 – 0.89) during short-distance (< 40 km) and prologue time trials (< 10 km) and still 78 – 80 % during long-distance (> 40 km) and uphill time trials [20]. Fernandez-Garcia et al. investigated the exercise intensity during the Tour de France with some of its mountain stages very similar in the course profile to that of the Ötztal Radmarathon [8]. In these special mountain stages they found the following distribution of HR ranges: 16 % HR_{re}, 33 % HR_{ma}, 36 % HR_{ia}, and 15 % HR_{an}. In contrast to professional cycling, data focusing on amateurs, i. e. young elite cyclists not having reached the professional category yet, are sparse and limited to a single study addressing the HR response to common road cycling races [22]. However, regarding the field of cycle-touring events and the "break-points" of the significantly less-trained, recreational athlete, no study at all has been done so far.

The average workload observed in our study was impressively high. Intense aerobic and anaerobic exercise intensities together amounted to a percentage of 53.5 % (5 h 30 min) of total race time

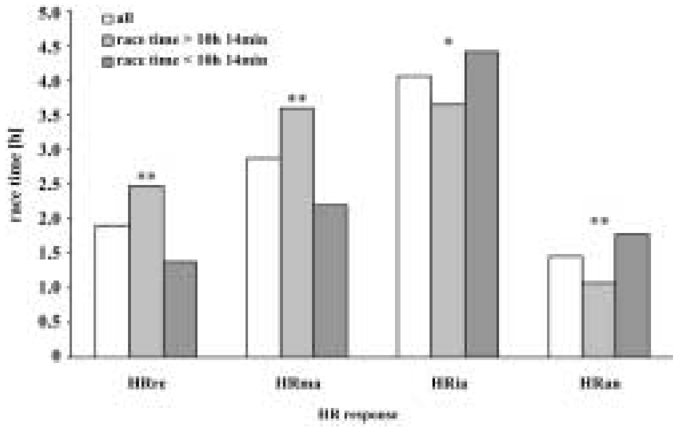

Fig. **2** Heart rate (HR) response in the total group (n = 14) and in differently fast subgroups separated according to race time (race time >10 h 14 min; n = 7; race time < 10 h 14 min; n = 7).

with sole anaerobic intensity ≤ 14% (1 h 26 min). This result strongly corresponds to that of professional cycling where a similar combined amount of HR_{ia} and HR_{an} of 51% was found during mountain stages of comparable workload [8]. Apart from professionals also amateurs are known to be able to sustain impressing loads. Palmer et al. showed that well-trained amateurs perform road races lasting 2 – 3 h (~ 110 km) at mean $HR_{average}/HR_{max}$ ratios of 0.79 – 0.82 [22]. In shorter individual time trials of 16 km and 5.5 km distance (hill climb) they even experience $HR_{average}/HR_{max}$ ratios of 0.91 – 0.93. It is not surprising that the mean $HR_{average}/HR_{max}$ ratio of our study, demonstrated to be 0.77 during long-term high mountain cycling, is somewhat diminished compared to that during flat stages of usual distance [8]. This reduction of mean $HR_{average}/HR_{max}$ confirms once more that exercise intensities decrease with increasing duration of efforts. Furthermore we could observe a significant shift in the HR response towards lower rates in all subjects during the course of race – most probably due to the inevitable glycogen depletion occurring during any long-term exercise [9]. The magnitude of HR decline was about 10% and very similar to previous comparable data [19].

Our study reveals that the vast majority of a cycling marathon is done under aerobic conditions ($HR_{re} + HR_{ma} + HR_{ia} \geq 86\%$ of total race time or 8 h 48 min) with the classical aerobic range ($HR_{ma} + HR_{ia}$) amounting to 67.4% or 6 h 54 min. This percentage is again well comparable to professional cycling with respect to the requirements of energy supply. In mountain stages of the Tour de France and of the Vuelta a Espana the percentage of aerobic metabolism was demonstrated to be 69 and 66% respectively [8]. This nearly identical amount of aerobic exercise intensity in both recreational and professional cyclists proves that the aerobic metabolism is the basis of energy supply in long-term cycling for any athletic population independent of its performance capacity. The main difference between them lies in the cycling speed with which they are able to perform such competitions ranging from the professional's top speed of 30 – 35 km/h to the signifcantly lower average speed of 22.5 km/h observed in the hobby cyclists of our study.

We found that faster athletes had an increased $HR_{average}/HR_{max}$ ratio and a higher percentage of intense HRs (Fig. **2**). Compared with slower competitors (race time > 10 h 14 min; average speed < 22.5 km/h), they endured HR_{ia} and HR_{an} of 45.2 and 18.2% versus 33.8 and 10% respectively (Fig. **2**). This correlation between race time and intense HRs suggests that race performances are dependent on exercise intensity, and higher intensity borne for longer periods is likely to lead to better race results. However, this assumption may only be drawn with caution and in consideration that group dynamics of cyclists ("drafting"), race tactics and individual motivation coinfluence the HR response as well, especially in the recreational cyclist [22]. Considering the long duration of the event, the extent of anaerobic exercise intensity was impressively high, i.e. 14% of total race time or 1 h 26 min. This finding seems to be of particular importance and of practical applicability as "Cycle-Touring Events" like the Ötztal Radmarathon enjoy growing popularity among manifold athletic groups. Since we also found a moderate exercise-induced release of cardiac troponin I (cTnI) in 5 out of these 14 asymptomatic athletes (34%) as published previously [17], we advise all participants of such competitions at least to undergo careful cardiovascular check-up looking for subtle evidence of myocardial dysfunction. In that larger study population of 38 athletes not examined for HR response, we had observed a significant correlation between race time and cTnI status with faster athletes more likely to feature post-exercise cTnI elevations [17]. The clinical meaning of positive post-exercise levels of cardiac troponins remains to be elucidated in future. In the present study, however, no respective correlation between HR response, race time and cTnI status was found – indicating that other causes than high exercise intensity may coinfluence this stress-induced troponin release following prolonged strenuous exercise [23].

Several factors potentially influencing the evaluation affect the HR response to exercise. High temperature and dehydration make it rise [24] whereas glycogen depletion and adaption to training reduce it [9]. Before the race all cyclists were instructed to maintain adequate fluid and nutritional intake rich in carbohydrates. Very small weight losses and several laboratory findings (e.g. unchanged haematocrit levels and stable plasma volume immediately after competition; Table **2**) are evidence of a constant volume status and indicate that significant dehydration did not occur [18]. Furthermore the fine weather conditions on that day did certainly minimize the external influences. Hence the impact of these confounding factors should be small regarding potential under- or overestimation of intensity categories. We are also aware that the methodology of the study has a limitation. For logistic reasons we could not perform extensive laboratory exercise testing to obtain more precise definition of the athletes' thresholds, and therefore used various percentages of HR_{max} for the classification of exercise intensity. Without precise information on the individual's thresholds some misquantification of exercise intensity could have happened. The magnitude of error, however, should be negligible and not be of significance with respect to the finding of the study [1,14].

In conclusion, our study is the first to evaluate the exercise intensity of recreational cyclists undergoing strenuous marathon cycling. Based on the HR response, the results show that the energy supply during a cycle-touring event is predominantly met by the aerobic metabolism with a non-negligible contribution of anaerobic energy. The exercise intensity observed is high and does not significantly differ from that of professionals. With regard to the extraordinary cardiovascular strains incident thereto, a thorough pre-race medical check-up appears advisable and essential for the athlete's safety.

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