

## Case report

# PHYSIOLOGICAL EFFECTS OF AN ULTRA-CYCLE RIDE IN AN AMATEUR ATHLETE - A CASE REPORT

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### ABSTRACT

The physiological effects of ultraendurance exercise are poorly investigated. The present case report describes the exercise intensity of ultraendurance cycling and its physiological impacts on various organ functions in an amateur cyclist performing the Ötztal Radmarathon *twice en bloque* in a circuit of 2 identical laps (distance 460 km; cumulative altitude difference 11,000 m). In a pre-race laboratory test the athlete's performance capacity was measured as the maximal aerobic power ( $VO_{2max} = 70 \text{ ml.kg}^{-1}.\text{min}^{-1}$ ), a maximal power output ( $5.7 \text{ W.kg}^{-1}$ ) and lactate threshold of 89%. The overall intensity during the ride was moderate ( $HR_{mean} = 131 \text{ b.min}^{-1}$ ;  $\%HR_{max} = 0.71$ ) and significantly declined during the course of the race. Extensive biochemical laboratory testing performed pre- and post-race excluded major exercise-induced organ disturbances. For further confirmation and better understanding of the physiological effects of ultra-cycle events future studies of larger athlete populations are required.

**KEY WORDS:** Ultraendurance event, exercise intensity, heart rate, organ functions, cycling.

### AMATÖR BİR SPORCUDA ULTRA BİSİKLET YARIŞININ FİZYOLOJİK ETKİLERİ: OLGU SUNUSU

#### ÖZET

İleri derecede dayanıklılık egzersizinin fizyolojik etkileri araştırmaları yetersizdir. Sunulan bu olgu raporunda 2 turdan oluşan (mesafe 460km; gittikçe artan rakım farklılığı 11000m) Ötztal Radmarathonu'nu tamamlayan amatör bir bisikletçide ultraendurans bisiklet egzersizinin şiddeti, değişik organ fonksiyonları üzerine olan fizyolojik etkileri tarif edilmektedir. Sporcunun performans kapasitesi maksimal aerobik güç ( $VO_{2max} = 70 \text{ ml.kg}^{-1}.\text{min}^{-1}$ ), maksimal güç oluşumu ( $5.7 \text{ W.kg}^{-1}$ ) ve laktat eşiği (%89) olmak üzere yarış öncesi laboratuvar testleri ile ölçüldü. Yarışın toplam şiddeti orta düzeydeydi ( $HR_{mean} = 131 \text{ atım.dak}^{-1}$ ;  $\%HR_{max} = 0.71$ ) ve yarış boyunca anlamlı bir şekilde düşmekteydi. Yarış öncesi ve sonrası böyle bir egzersizin ortaya çıkaracağı organ rahatsızlıkları kapsamlı biyokimyasal laboratuvar testleri ile ortaya konuldu. Ultra bisiklet aktivitelerinin fizyolojik etkilerini daha iyi anlayabilmek ve ileri kanıtlar ortaya koyabilmek için daha geniş sporcuyla içeren ileri çalışmalar gereksinim vardır.

**ANAHTAR KELİMELER:** Ultraendurans, şiddet, kalp atım sayısı, organ fonksiyonları, bisiklet.

### Introduction

Whereas a vast amount of research has focused on the physiological effects of typical endurance events lasting for 1-3 hours, much less is understood about the impacts of ultraendurance exercise (i.e. > 4h)

(Hawley and Hopkins, 1995; Kreider, 1991). The current information about ultraendurance activities is mainly derived from the field of triathlon (O'Toole et al., 1989a; Sleivert and Rowlands, 1996). Little is known about the effects of sole ultraendurance cycling lasting for more than 20 hours.

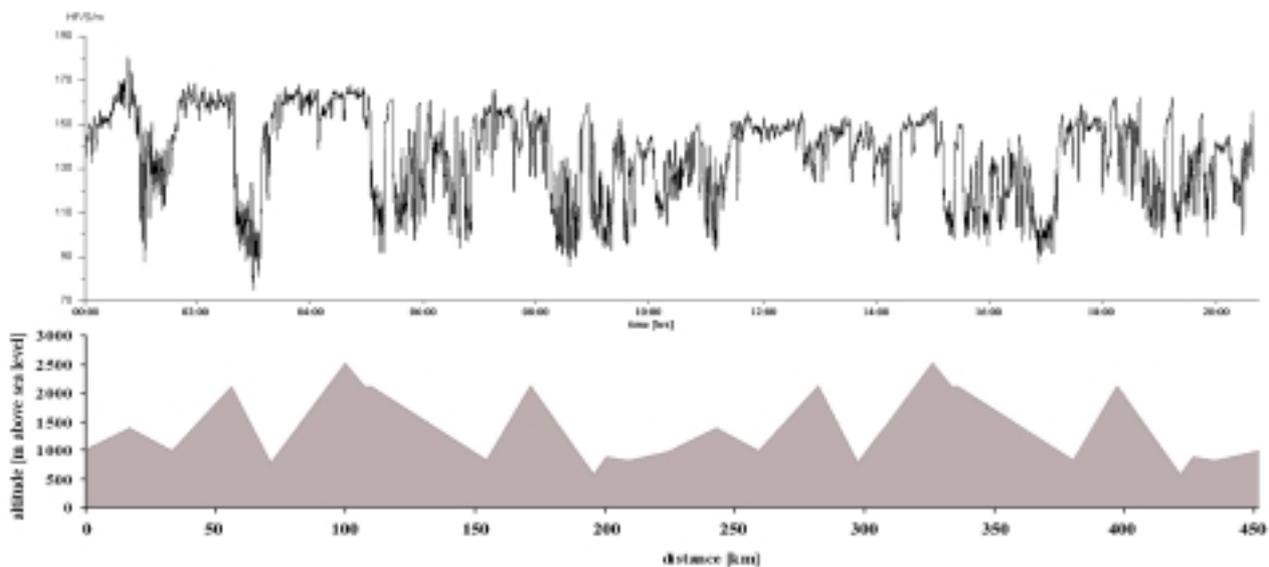
The Ötztal Radmarathon is a very challenging 1-day cycling race characterised by a workload comparable to that of the king's stages of professional cycling (e.g. Tour de France, Giro d' Italia). In 1999 an experienced male amateur cyclist performed this marathon twice en bloque in a circuit of 2 identical laps (i.e. distance: 460 km; cumulative altitude difference: 11,000 m). It was the purpose of the present case study to describe the impacts of ultramarathon cycling as well as to uncover potential health hazards which may attend such an ultraendurance event. We therefore performed 1) pre-race maximal exercise testing for the description of the athlete's performance capacity, 2) heart rate (HR) monitoring during the race for the estimation of exercise intensity, and 3) extensive pre- and post-race laboratory blood and urine testing to assess the

influence of 460 km - cycling on various organ functions.

## Methods

### *Characteristics of the race*

The Ötztaler Radmarathon is a challenging 1-day cycling race yearly held in the Alps of the Tyrol (Austria). In August 1999 the amateur athlete examined cycled it twice en bloque in a circuit of 2 identical laps. The total workload consisted in 460 km with a cumulative altitude difference of 11,000 m at an altitude of 550 - 2500 m above sea level. Four mountain passes per lap had to be mastered twice: Brennerpass (1374 m), Jaufenpass (2097 m), Timmelsjoch (2509 m) and the Kühtai (2097 m) (Figure 1).



**Figure 1.** The athlete's heart rate response during the ultra-cycle event. Heart rate profile (*top*); Course profile (*bottom*)

The race took place under dry and fine weather conditions. During the race the temperature ranged from 14 - 21° C and relative humidity from 55 - 85%. The subject had provided written informed consent in accordance with the guidelines established by the Institutional Ethics Committee.

### *Pre-race laboratory exercise testing*

An incremental 50-W/3-min symptom-limited maximal exercise test was performed one week before the marathon on a cycle ergometer ER 800 (Ergoline®, Bitz, Germany) to assess the athlete's performance capacity. To measure minute BTPS ventilation (VE), STPD oxygen uptake (VO<sub>2</sub>) and STPD carbon dioxide output (VCO<sub>2</sub>) we employed open circuit spirometry (Oxycon pro, Jaeger®, Würzburg, Germany; CPX Medical Graphics).

Capillary blood samples were obtained from the ear lobe immediately after each workload. Blood lactate concentration [Lac, mmol.L<sup>-1</sup>] was measured by the use of the lactate analyzer Ebio plus (Eppendorf®, Hamburg, Germany).

### *Heart rate (HR) monitoring during the ultramarathon*

The HR was recorded during the whole ultramarathon by the use of Polar Vantage NV telemeters (Polar Electro Oy, Finland). The recorded data was 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 using the "Karvonen formula" (Karvonen et al., 1957) by

multiplying the heart rate reserve (HRR) achieved in the pre-race laboratory testing ( $HRR = HR_{\max} - HR_{\text{rest}}$ ) by the factors 0.5, 0.7, 0.9 and by adding these values to the HR at rest ( $HR_{\text{rest}}$ ). The following HR ranges were defined: “long-term endurance range“ ( $HR_{\text{lte}} < 119$  beats per minute ( $b \cdot \text{min}^{-1}$ ) ( $<50\%$  HRR); “extensive aerobic range“ ( $HR_{\text{ea}} = 119-145$   $b \cdot \text{min}^{-1}$  ( $50-70\%$  HRR); “intensive aerobic range“ ( $HR_{\text{ia}} = 145-171$   $b \cdot \text{min}^{-1}$  ( $70-90\%$  HRR); “high intensity range“ ( $HR_{\text{hi}} > 171$   $b \cdot \text{min}^{-1}$  ( $>90\%$  HRR) (ACSM, 1995; Davies and Convertina, 1975).

#### Biochemical laboratory examinations

Blood and urine samples were taken the day before, immediately after and 24h after exercise. Blood samples were obtained by venepuncture 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 immediately after the finish. Urine samples were taken at the same time points. We measured the plasma and urinary concentrations of the following markers: sodium ( $\text{Na}^+$ ), potassium ( $\text{K}^+$ ), chloride ( $\text{Cl}^-$ ) by ion-sensitive electrodes (Hitachi analyzer 717 and 911; Roche Diagnostics, Basel, Switzerland), and calcium ( $\text{Ca}^{2+}$ ), magnesium ( $\text{Mg}^{2+}$ ) by photometry on the same analyzers. The activity of creatine kinase (CK) was determined colorimetrically by using the standard method of the “Deutsche Gesellschaft für Klinische Chemie“. Cardiac TnI (cTnI) was assessed by means of two step sandwich microparticle enzyme-immunoassay method on an AxSYM analyzer (Abbott Diagnostika, Wiesbaden, Germany), C-reactive protein (CRP) by an immunoturbidimetric assay (Tina-quant®, Roche Diagnostics, Basel, Switzerland), creatinine by the Jaffee reaction, and serum protein by the Biuret method. The red blood cell count, haematocrit (Hct), haemoglobin (Hb), leukocytes and thrombocytes, were measured in an automated cell counter (Coulter Gene S analyzer). The concentrations of all other parameters measured were assessed by standard methods. The percentage change in plasma volume ( $\% \Delta \text{PV}$ ) was calculated from pre- and post-exercise levels of Hct and Hb according to the equation of Strauss et al. (1951).

## Results

#### Anthropometric variables and race results

The 36-year-old athlete was 1.78 m tall, his body mass and body mass index were 70 kg and  $22 \text{ kg} \cdot \text{m}^{-2}$ , respectively. His training in 1999 amounted to 12,000 km. The race time achieved was 20h 51min, the lap times were 9h 40min and 11h 11min. Although he drank 8 litres of fluids rich in carbohydrates during the race he lost 3 kg which he regained in the following 24 hours.

#### Athlete's performance profile in the pre-race laboratory exercise testing

The athlete's  $HR_{\text{rest}}$ ,  $HR_{\max}$  and HRR were 54, 184 and 130  $b \cdot \text{min}^{-1}$ , respectively. The subjects' laboratory maximal power output ( $W_{\max}$ ) was 400 W ( $5.7 \text{ W} \cdot \text{kg}^{-1}$ ) with 352 W ( $5.0 \text{ W} \cdot \text{kg}^{-1}$ ) at the onset of blood lactate accumulation ( $W_{\text{OBLA}}$ ). The maximal values of oxygen uptake ( $\text{VO}_{2\max}$ ), respiratory exchange ratio (RER) and [Lac] were 4.87  $\text{L} \cdot \text{min}^{-1}$  ( $70 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ), 1.09 and 9.8  $\text{mmol} \cdot \text{L}^{-1}$ , respectively. For the various performance parameters see table 1.

**Table 1.** The athlete's performance profile in the incremental maximal exercise test

%HR	HR	%HR <sub>max</sub>	P	%VO <sub>2max</sub>	VO <sub>2</sub>	RER	Lac
50	119	≅ 65	1.9	43	30	0.80	0.5
60	132	≅ 72	2.3	47	33	0.87	0.6
70	145	≅ 79	3.0	59	41	0.89	1.0
80	158	≅ 86	3.7	71	50	0.92	1.8
90	171	≅ 93	4.5	82	57	0.95	3.7
93	175	≅ 95	5.0	89	62	0.99	4.0
100	184	100	5.7	100	70	1.09	9.8

HR [ $b \cdot \text{min}^{-1}$ ]; P=power [ $\text{W} \cdot \text{kg}^{-1}$ ]; VO<sub>2</sub> [ $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ]; Lac [ $\text{mmol} \cdot \text{L}^{-1}$ ]

#### Heart rate response to the ultramarathon

The athlete's HR response related to the course profile is given in figure 1.  $HR_{\text{lte}}$  were measured during the downhill of the passes,  $HR_{\text{ea}}$  during the flat sections of the course and the more intensive HRs ( $HR_{\text{ia}} + HR_{\text{hi}}$ ) exclusively during the long-lasting ascents of the 8 passes. Nearly the entire exercise (99.6%) was done under aerobic conditions ( $HR_{\text{lte}} + HR_{\text{ea}} + HR_{\text{ia}} = 20\text{h } 46\text{min}$ ). During the race a marked shift in the HR response towards lower rates was observed. The different HR response to the 1<sup>st</sup> and 2<sup>nd</sup> lap of the ultramarathon is illustrated in figure 2. Athlete's mean HR ( $HR_{\text{mean}}$ ) measured during the 1<sup>st</sup> lap was 138 bpm and 124 during the 2<sup>nd</sup> one.  $HR_{\max}$  achieved in the laboratory testing was 184 bpm. The calculated  $HR_{\text{mean}}/HR_{\max}$  ratios, therefore, were 0.75 and 0.67 in the 1<sup>st</sup> and 2<sup>nd</sup> lap respectively. Comparing lap 1 with lap 2  $HR_{\text{mean}}$  declined by 10.1%, and  $HR_{\text{mean}}/HR_{\max}$  ratio by 10.7%. Differences between the two laps (i.e. changing exercise intensity, lap time, average speed) are given in table 2.

#### Biochemical laboratory examinations

Most parameters remained within the normal range of reference prior to and after the ultramarathon. There were small increases in creatinine, urea, uric acid, CK, lactate dehydrogenase (LDH), leukocytes and CRP. All results of the markers investigated before race, immediately after and 24h after are given in table 3.

**Table 2.** Lap characteristics and exercise intensity of the ultramarathon

	Total race	1 <sup>st</sup> lap	2 <sup>nd</sup> lap
Race time	20h 51min	9h 40min	11h 11min
Average speed (km.h <sup>-1</sup> )	22.0	23.8	19.7
HR <sub>mean</sub> (b.min <sup>-1</sup> )	131	138	124
%HR <sub>max</sub>	0.71	0.75	0.67
HR <sub>lte</sub> (<119 b.min <sup>-1</sup> )	30.1 (6h 17min)	24.8 (2h 24min)	34.7 (3h 53min)
HR <sub>ea</sub> (119-145 b.min <sup>-1</sup> )	38.6 (8h 3min)	23.5 (2h 16min)	51.7 (5h 47min)
HR <sub>ia</sub> (145-171 b.min <sup>-1</sup> )	30.9 (6h 26min)	50.8 (4h 55min)	13.6 (1h 31min)
HR <sub>hi</sub> (>171 b.min <sup>-1</sup> )	0.4 (5min)	0.9 (5min)	0.0

## Discussion

The popularity of ever-more grueling ultraendurance racing events is increasing as well as the attendance of heterogeneously trained athletes. More information on the demands and effects of ultraendurance exercise is necessary for the prophylaxis of potential health hazards as well as for creation of adequate training regimens for successful longterm performance. The analyses of ultraendurance athletes have provided new insights into the limits of human

performance capacity and into medical complications when going beyond the physical limits (O'Toole, 1989; O'Toole et al., 1989a; 1989b). The available information on ultraendurance events is restricted to the field of triathlon and ultramarathon running. In contrast little is known about specialists undergoing sole ultraendurance cycling. It was the purpose of the present case report to contribute to this interesting area and to provide some relevant information. The observations made are discussed under the following 3 aspects:

**Table 3.** Physiological effects of ultraendurance cycling on selected biochemical parameters (values in brackets indicate normal range).

	Before race	Immediately after	24h after
Creatinine (0.70 - 1.40 mg.L <sup>-1</sup> )	0.96	0.93	1.04
Urea (10 - 50 mg.dL <sup>-1</sup> )	33	58	57
Uric acid (2.40 - 7.50 mg.dL <sup>-1</sup> )	5.0	5.9	5.9
Protein (6.3 - 8.2 g.dL <sup>-1</sup> )	7.41	7.67	7.54
CK (12 - 126 U.L <sup>-1</sup> )	43	420	482
LDH (120 - 240 U.L <sup>-1</sup> )	200	239	266
cTnI (< 0.05 µg.L <sup>-1</sup> )	n.d.	n.d.	n.d.
CRP (0 - 0.7 mg.L <sup>-1</sup> )	< 0.7	2.03	1.89
Na <sup>+</sup> (135 - 152 mmol.L <sup>-1</sup> )	142	145	144
K <sup>+</sup> (3.4 - 4.6 mmol.L <sup>-1</sup> )	4.0	3.5	3.5
Cl <sup>-</sup> (95 - 110 mmol.L <sup>-1</sup> )	102	98	101
Ca <sup>2+</sup> (2.1 - 2.7 mmol.L <sup>-1</sup> )	2.27	2.46	2.15
Mg <sup>2+</sup> (0.60 - 0.95 mmol.L <sup>-1</sup> )	0.83	0.97	0.91
RBC (4.4 - 5.9 x 10 <sup>12</sup> .L <sup>-1</sup> )	4.39	4.42	4.15
Hct (0.40 - 0.52)	0.40	0.41	0.39
Hb (13.3 - 17.7 g.dL <sup>-1</sup> )	14.0	14.2	13.2
%ΔPV (related to pre-race)	-	- 2	+ 9
Leukocytes (4 - 10 x 10 <sup>9</sup> .L <sup>-1</sup> )	5.4	12.8	9.7
Thrombocytes (140 - 400 x 10 <sup>9</sup> .L <sup>-1</sup> )	261	325	275

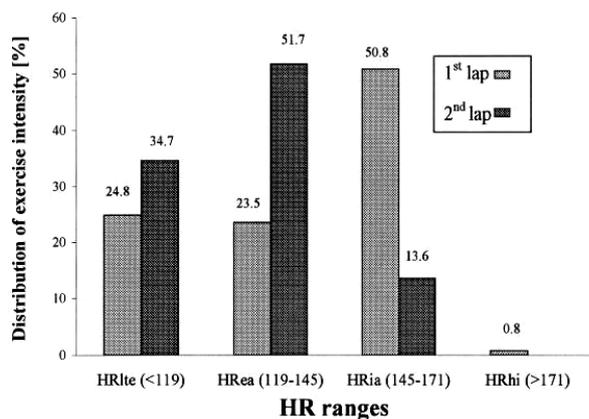
n.d. = not detectable

### Physiological profile

Ultraendurance athletes have physiological capacities similar to those of traditional endurance athletes. For instance male triathletes have mean VO<sub>2max</sub> values of 49, 67 and 69 ml.kg<sup>-1</sup>.min<sup>-1</sup> on the arm ergometer, cycle ergometer and treadmill respectively which corresponds well to the aerobic

capacity of swimmers (arm ergometer) but is also below that of professional cyclists (cycle ergometer) or distance runners (treadmill) (O'Toole, 1989; O'Toole et al. 1989b). This similar aerobic performance capacity also explains why many endurance athletes successfully compete in ultraendurance events as well. Training for

ultraendurance events involves moderate to high volume and low to moderate intensity training (O'Toole, 1989). In his race preparation our athlete cycled 12,000 km in the preceding 6 months ( $\approx 500 \text{ km.wk}^{-1} \approx 14\text{-}16 \text{ training-h.wk}^{-1}$ ). The athlete's training regimen corresponded well to the usual ultramarathon cycling preparation ( $600\text{-}1500 \text{ km.wk}^{-1}$ ) and to the existing knowledge that very large training volumes are neither necessary for successful competition in ultraendurance events nor for the maintenance of race efficiency (Laursen and Rhodes, 2001). The athlete's performance profile as obtained from pre-race laboratory testing was characterised by a high lactate threshold ( $89\%$  of  $\text{VO}_{2\text{max}}$ ) and a high power output at submaximal workloads whereas the maximal performance parameters [ $\text{VO}_{2\text{max}} = 70 \text{ ml.kg}^{-1}.\text{min}^{-1}$ ;  $\text{W}_{\text{max}} = 5.7 \text{ W.kg}^{-1}$ ] were well below those of professional cyclists characterizing the athlete as an amateur cyclist.



**Figure 2.** Comparison of heart rate [HR] response between the 2 laps of the ultramarathon.  $\text{HR}_{\text{lte}}$  = long-term endurance HR ( $<119 \text{ b.min}^{-1}$ );  $\text{HR}_{\text{lea}}$  = extensive aerobic HR ( $= 119\text{-}145 \text{ b.min}^{-1}$ );  $\text{HR}_{\text{lia}}$  = intense aerobic HR ( $= 145\text{-}171 \text{ b.min}^{-1}$ );  $\text{HR}_{\text{hi}}$  = high-intensity HR ( $>171 \text{ b.min}^{-1}$ )

#### *Exercise intensity during the ultramarathon*

Ultraendurance competitions require the ability to maintain a steady long-term performance at a high exercise intensity. As expected, the overall intensity observed in the amateur was moderate, i.e.  $\text{HR}_{\text{mean}} = 130 \text{ b.min}^{-1}$ ,  $\text{HR}_{\text{mean}}/\text{HR}_{\text{max}} = 0.71$  which corresponds to an average workload of  $47\%$  of  $\text{VO}_{2\text{max}}$  as obtained in the laboratory testing. This  $\text{HR}_{\text{mean}}/\text{HR}_{\text{max}}$  ratio of  $0.71$  is clearly below the  $\text{HR}_{\text{mean}}/\text{HR}_{\text{max}}$  ratios of  $0.79 - 0.82$  in comparable amateur cyclists when they compete in road races of usual distance ( $\approx 110 \text{ km}$ ) lasting for 2-3 hours (Palmer et al., 1994) and still below that of Cycle-Touring events ( $\text{HR}_{\text{mean}}/\text{HR}_{\text{max}}$  ratio =  $0.77$ ) lasting for more than 10 hours (Neumayr et al., 2002c). During the course of the ultramarathon a marked

shift in the HR response towards lower rates could be observed. Between the 1<sup>st</sup> and 2<sup>nd</sup> lap  $\text{HR}_{\text{mean}}/\text{HR}_{\text{max}}$  ratio decreased by  $10.7\%$  from  $0.75$  to  $0.67$ , and average speed by  $17.2\%$  from  $23.8$  to  $19.7 \text{ km.h}^{-1}$ . This magnitude of HR decline corresponds well to previous comparable data gained from triathletes (O'Toole et al., 1998) and is likely to be caused by the ongoing glycogen depletion through the arduous exertion despite an estimated energy intake of  $9,800 \text{ kcal}$  (García-Rovés et al., 1998). Nearly the entire workload was done under aerobic conditions ( $\text{HR}_{\text{lte}} + \text{HR}_{\text{lea}} + \text{HR}_{\text{lia}} = 99.6\%$  or  $20\text{h } 46\text{min}$ ). Despite the tough course profile the amount of sole anaerobic work rate was negligible (i.e.  $\text{HR}_{\text{hi}} = 0.4\%$  or  $5\text{min}$ ). Exercise intensity was below  $70\%$   $\text{VO}_{2\text{max}}$  [ $\approx \text{HR} < 158 \text{ b.min}^{-1}$ ;  $\approx 85\% \text{ HR}_{\text{max}}$ ] during  $87\%$  of the race and below  $60\%$   $\text{VO}_{2\text{max}}$  [ $\approx \text{HR} < 145 \text{ b.min}^{-1}$ ;  $\approx 80\% \text{ HR}_{\text{max}}$ ] during  $73\%$  (O'Toole et al., 1989). About the half ( $49\%$ ) of the total distance was performed at an intensity of between  $50\text{-}70\%$   $\text{VO}_{2\text{max}}$  [ $= 60\text{-}80\% \text{ HRR}$ ;  $\approx 132 \text{ b.min}^{-1} < \text{HR} < 158 \text{ b.min}^{-1}$ ;  $\approx 72\% < \text{HR}_{\text{max}} > 85\%$ ].

#### *Physiological effects on various organic functions*

Various medical concerns have been raised regarding ultraendurance exercise ranging from subclinical myocardial damage to electrolyte disturbances, dehydration, haemoconcentration and renal functional impairment (Neumayr et al., 2001; Neumayr et al., 2002a; Irving et al., 1990). In this athlete none of the symptoms of the mentioned deteriorations of organ functions was detected. The magnitude of post-exercise plasma volume expansion ( $+9\%$ ) and corresponding Hct decline ( $-2\%$ ) was very similar to that of common Cycle-Touring events ( $+12\%$  and  $-3\%$ , respectively) (Neumayr et al., 2002b). There were slight and temporary increases in CRP and leukocytes as unspecific response to the enormous exercise stress. Negative values of cardiac troponin I exclude asymptomatic cardiac injury in this athlete (Neumayr et al., 2001; Neumayr et al., 2002a). Renal functional parameters and electrolytes remained stable and nearly unchanged. All laboratory testing executed pre- and post-race appeared to exclude major organ disturbances in the asymptomatic athlete suggesting ultraendurance cycling to be safe when adequately prepared. In this context, however, it is important to state that no general conclusions can be drawn from a case report and that the finding cannot be applied to a wider athlete population.

#### References

- American College of Sports Medicine (ACSM). (1995) General principles of exercise prescription. In:

- ACSM's guidelines for exercise and prescription, 5<sup>th</sup> ed. Baltimore: Williams and Wilkins, 153-176.
- Davies, J.A., and Convertina, V.A. (1975) A comparison of heart rate methods for predicting endurance training intensity. *Medicine and Science in Sports and Exercise* **7**: 295.
- García-Rovés, P.M., Terrados, N., Fernández, F., and Patterson, A.M. (1998) Macronutrients intake of top level cyclists during continuous competition. *International Journal of Sports Medicine* **19**: 61-67.
- Hawley, J.A., and Hopkins, W.G. (1995) Aerobic glycolytic and aerobic lipolytic power systems; a new paradigm with implications for endurance and ultraendurance events. *Sports Medicine* **19**: 240-250.
- Irving, R.A., Noakes, T.D., Burger, S.C., Myburgh, K.H., Querido, D., Van Zyl Smit, R. (1990) Plasma volume and renal function during and after ultramarathon running. *Medicine and Science in Sports and Exercise* **22**: 756-761.
- Karvonen, M.J., Kentala, E., and Mustala, O. (1957) The effects of training on heart rates. A "longitudinal" study. *Annales Medicinæ Experimentalis et Biologiae Fenniae* **35**: 307-310.
- Kreider, R.B. (1991) Physiological considerations of ultraendurance performance. *International Journal of Sports and Nutrition* **1**: 3-27.
- Laursen, P.B., and Rhodes, E.C. (2001) Factors affecting performance in an ultraendurance triathlon. *Journal of Sports Medicine* **31**: 195-209.
- Neumayr, G., Gaenger, H., Pfister, R., Sturm, W., Schwarzacher, S.P., Eibl, G., Mitterbauer, G., and Hoertnagl, H. (2001) Plasma levels of cardiac troponin I after prolonged strenuous endurance exercise. *American Journal of Cardiology* **87**: 369-371.
- Neumayr, G., Pfister, R., Mitterbauer, G., Maurer, A., Gänzer, H., Sturm, W., and Hörtnagl, H. (2002a) Effect of the "Race Across The Alps" in elite cyclists on plasma cardiac troponin I and T. *American Journal of Cardiology* **89**: 484-486.
- Neumayr, G., Pfister, R., Mitterbauer, G., Gänzer, H., Joannidis, M., Eibl, G., and Hörtnagl, H. (2002b) Short-term effects of prolonged strenuous endurance exercise on the level of haematocrit in amateur cyclists. *International Journal of Sports Medicine*, in press.
- Neumayr, G., Pfister, R., Mitterbauer, G., Gänzer, H., Sturm, W., Eibl, G., and Hörtnagl, H. (2002c) Exercise intensity of Cycle-Touring events. *International Journal of Sports Medicine*, in press.
- Palmer, G.S., Hawley, J.A., Dennis, S.C., and Noakes, T.D. (1994) Heart rate responses during a 4-d cycle stage race. *Medicine and Science in Sports and Exercise* **26**: 1278-1283.
- O'Toole, M.L. (1989) Training for ultraendurance triathlon. *Medicine and Science in Sports and Exercise* **21**: S209-213.
- O'Toole, M.L., Douglas, P.S., and Hiller, W.D. (1989a) Lactate, oxygen uptake, and cycling performance in triathletes. *International Journal of Sports Medicine* **10**: 413-418.
- O'Toole, M.L., Douglas, P.S., and Hiller, W.D. (1989b) Applied physiology of a triathlon. *Sports Medicine* **8**: 201-225.
- O'Toole, M.L., Douglas, P.S., and Hiller, W.D. (1998) Use of heart rate monitors by endurance athletes: lessons from triathletes. *Journal of Sports Medicine and Physical Fitness* **38**: 181-187.
- Sleivert, G.G., and Rowlands, D.S. (1996) Physical and physiological factors associated with success in the triathlon. *Sports Medicine* **22**: 8-18.
- Strauss, M.B., Davies, R.K., Rosenbaum, J.D., and Rossmeisl EC. (1951) Water diuresis produced during recumbency by the intravenous infusion of isotonic saline solution. *Journal of Clinical Investigation* **30**: 862-868.

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