Athletic performance capacity in mountainbike sports with extremely strenuous more days lasting endurance impact

Performance determining and performance limiting factors during the Transalp Challenge

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DISSERTATION

submitted to the Faculty of Psychology and Sport Science
of the University of Innsbruck

in partial fulfillment of the requirements
for the degree of doctor of science

by

Katharina Wirnitzer

Advisor:

Univ.–Prof. DDr. Martin Burtscher

Stans, February 2009

Declaration in lieu of oath

Herewith I do solemnly declare that this present thesis was written by myself and did not use unauthorized support. The findings directly or indirectly taken from external sources are mentioned as this. This thesis was not submitted to any other examination authority.

Stans, 28. Februar 2009

Katharina Wirnitzer

DEDICATION

Dedicated to the weakest and most helpless individuals on the earth,
the animals abused and brutally tortured
in the experimental laboratories of scientific and medical institutions,
as well as in the pharmaceutical and chemistry industries,
for whom only death brings salvation and release.

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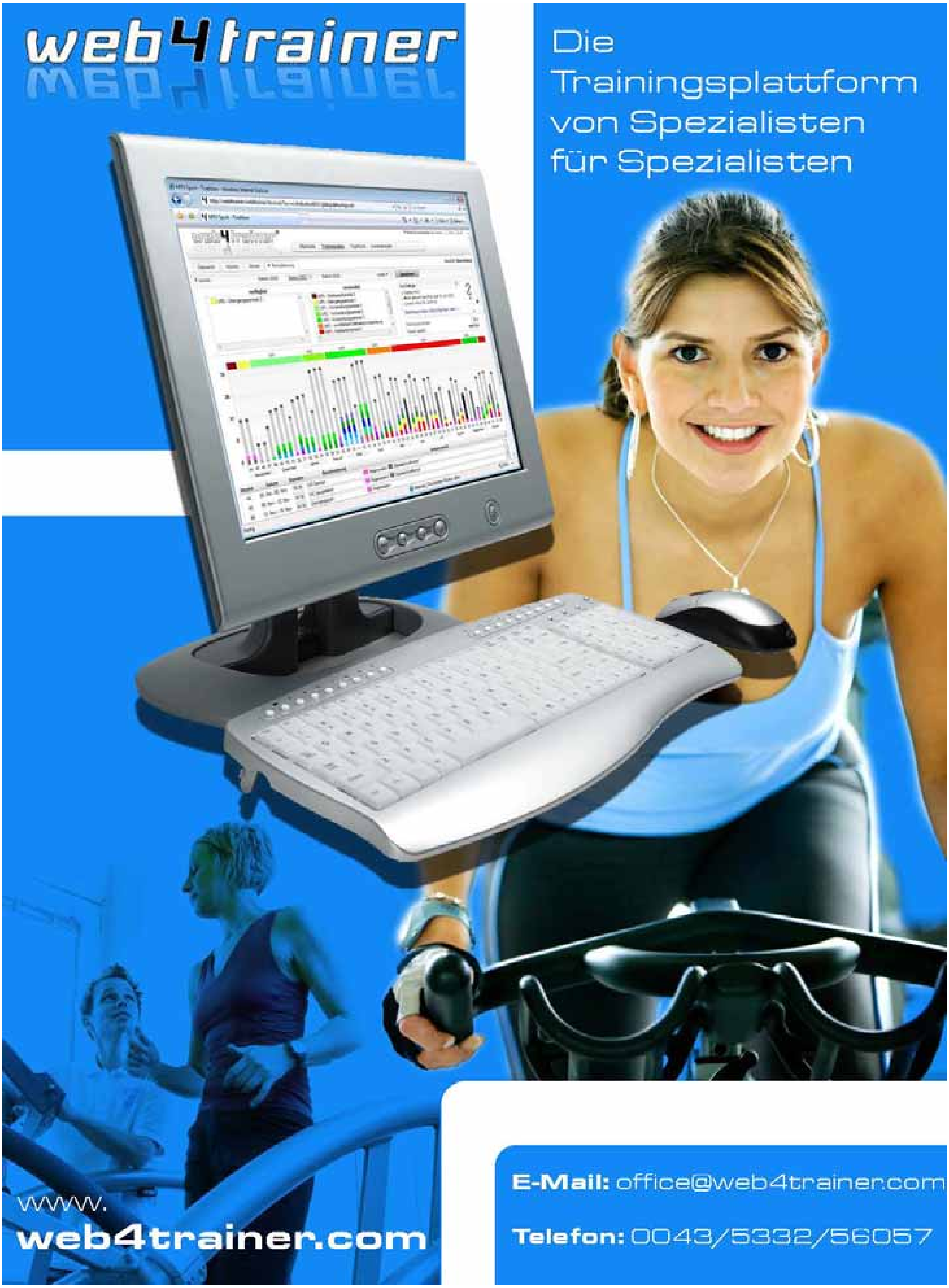
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- ✓ Uli Stanciu, founder of the Transalp Challenge and creator of several gorgeous ideas in the field of mountainbiking, for his kind and friendly support, help and cooperation relating to my work on this severe stage race. Image on the cover with friendly permission from 24th October 2007 (Uli Stanciu, bike–gps.com).

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Foreword

The current thesis presents a complete overview of my thesis project “bikeextreme” and the field study during the Transalp Challenge 2004. Considering the athletic performance capacity during this challenging and strenuous eight days lasting mountainbike stage race, a special focus was put on potential performance determining and performance limiting factors. This work is conceived as a so called “Sammel–Dissertation” with the main goal being to publish the results and findings of my investigation in international scientific peer–reviewed journals and scientific peer–reviewed publications.

In the following, given the current work is a compendium, I comment on motivation and historical overview in the introduction section as well as in the method and results section. Finally, an established discussion concludes this overview. For more details to any specific aspect the reader is referred to the papers released and listed within Chapter 7.

Contents

Abstract

In general, knowledge is sparse in the area of mountainbike (MTB) sports because MTBing is only a young and developing sports, compared to road cycling. Therefore, just a few studies have been published.

As the Tour de France is the ultimate multiple day event for professional road cyclists, the Transalp Challenge (TAC) is one of the most difficult MTB stage races in the world. Therefore, the purpose of this study was to determine the course, distribution and changes of the following parameters, caused by the the TAC 2004: Heart rate and Borg`s rate of perceived exertion (both indicators of exercise intensity), body water compartments, selected blood parameters as well as nutrient intake (energy and fluid intake) including vegan nutrition pattern.

Only athletes who successfully finished the TAC 2004 with complete data sets recorded comprised the basis of this examination. All subjects were well endurance trained amateur athletes and were experienced at competing in MTB marathon races.

This study was the first to

i) examine an extreme MTB stage race,
ii) determine the exercise intensity during one of the most important MTB stage races in the world, showing the TAC 2004 to be physiologically very demanding and heavily involving both the aerobic and anaerobic energy system,
iii) detect acute effects (decline in body water pools simultaneously with hemoconcentration), which probably occurred due to a combination of heat induced and exercise induced dehydration during the first stage of TAC 2004,
iv) describe long term adaptations (expansion in body water pools simultaneously with hemodilution), formerly shown to occur as a consequence of repeated strenuous endurance strains during the TAC 2004,
v) study a female athlete during this difficult multi–day MTB marathon race and
vi) report the dietary intake during the TAC 2004 , showing a well planned vegan diet to adequately meet the nutritional demands of severe MTB stage racing.

The present study might be useful to design specific training programs and to develop appropriate nutritional strategies to sustain the physical demands of severe MTB marathon and MTB stage race.

1. Introduction

1.1. Motivation

In the late 1980s, at the age of 14, I got my first mountainbike (MTB). From then on I was addicted to this new kind of cycling sport. Thus, to the best of my knowledge, I was one of about five female MTBers in my federal state. In the past decade I participated in several regional, national and international MTB marathon races (lasting one or even several days). Due to my passion, my whole family adopted this sport as their favourite leisure time activity.

Based on my passion for MTB sports and a deep and broad review of MTB specific literature available, which so far is sparse, I decided to write my thesis about the most challenging more days lasting MTB marathon race in the world, the Transalp Challenge (TAC), in the year 2004.

At the same time as undertaking my investigation in sports science, I reached the peak of my career as an MTB athlete by finishing the TAC 2004 with the final rank of 16th – I had never dreamt of exceeding my target bench mark of reaching the top 20.

1.2. Historical overview

In September 1976 a new kind of bicycle, the off–road bike or MTB, was created by four young men (Gary Fisher, Charly Kelly, Joe Breeze and Tom Ritchey) in California, USA (Gerig and Frischknecht 1996). The first MTB competitions were held in the early 1980s (Auferbauer 2007). Since then this new kind of cycling sports has grown rapidly. The first MTB World Championships to be officially recognized by the Union Cycliste Internationale (UCI) date back to 1990, with the first World Cup (WC) events having been held in 1991 (www.uci.ch).

The first MTB marathon ever held on 11th of August 1990 in Eschlikon/CH, indicates the history of the long distance category and laid the foundation for the biggest mass movement in the history of MTBing. From then on the number of long distance events exploded, along with the number of starters in these MTB marathon events. In the mid 1990s riders were glad to snatch a start (Lesewitz 2005). After Stefan Götz, Specialized (Lesewitz 2004): "Marathon was probably the best idea for MTB sports. It covers the whole spread of this sport."

Nowadays, MTB marathon is a public sport and a booming industry. There are about 120 MTB marathon events of all kinds listed in race calendar, with up to 10,000 participants (Lesewitz 2004). According to the UCI Rules (www.uci.ch/Modules/BUILTIN/getObject.asp?MenuId=MTkzNg&ObjTypeCode=FILE&type=FILE&

id=34424&), MTB races are divided into three types of events (UCI Rules, Chapter I §1, p. 1): Cross–country (XC), downhill and stage races. XC marathons (XCM) generally cover a closed circuit of at least 60 km in distance and last at least 3 hours. The XCM discipline is a mass start event. There are narrow tracks, paths through forests, rocky paths and the riders even have to ford streams (www.uci.ch).

Usually one day MTB marathon races can be characterized according to the total load of the race: a classic MTB marathon covers about 2400 m in altitude difference along with a distance of about 60 km, whereas extreme and ultraendurance (> 4 hours: Peters 2003) MTB marathons cover altitude differences of 3500 m to 7000 m along with distances of 70 km to 200 km while light courses (for beginners) have about 1000 m in altitude difference and distances of about 25 km.

The UCI Race Calendar (UCI Rules, Chapter I §3, p. 3) includes the XCM World Championship (officially held first in 2003 in Switzerland), XCM European Championship (officially held first in 2002 in Austria), XCM WC series (UCI Rules, Chapter VIII, §1, p. 24–25, www.uci.ch/templates/UCI/UCI5/layout.asp?MenuId=MTUzNDI) and numerous other global series, XCM stage races and XCM one day races. XCM has not yet gained acceptance as an Olympic event yet.

In the summer of 1990, the two German MTBers Andi Heckmaier and Uli Stanciu (founder of the TAC) were the first to cross the Central Alps, independently of each other (Lesewitz 2004, Scheele 2008).

In July 1998, the first TAC took place, following the model of the Tour de France. It was conceived as a multi–day competitive event for double teams (due to safety aspects) of both professional and recreational MTBers across the Central Alps (Figure 1). The UCI General Rules for stage races are met (UCI Rules, Chapter II §1, p. 6–7, Chapter VI §1, p. 22–23, Chapter VIII §2, p. 24–27). Today, three decades after the birth of the off–road bike, the term “Alpentransversale” is the term which is googled most often by European MTBers (Auferbauer 2007) and annually thousands of riders cross the (Eastern and Western) Alps on several different routes (Lesewitz 2005).

Figure 1. Course of Transalp Challenge 2004 (with permission from 24th October 2007) covering an altitude difference of 22500 m in a distance of 662 km, starting at Mittenwald/BRD (17th July 2004), passing the Tyrol/AUT and finishing at Riva del Garda/ITA (24th July 2004).

Therefore, the purpose of this field study was to investigate the TAC for the first time in order to determine the athletic performance capacity of MTBers. Moreover, physiological parameters and factors which might determine or limit MTB performance while competing in the TAC 2004 have been a specific objective of studying this severe XCM stage race.

2. Method

The concept in conducting a field study under authentic race burden during the TAC 2004 was supported by two researchers from the Australian Institute of Sport, Department of Physiology, amongst others working together with Cadel Evans, formerly one of the worlds best MTBers and, to date, professional road cyclist at the Pro–Tour Team Silence–Lotto.

The design of this study was partly based on the work of, and a specific citation within, the Master Thesis "Competitive mountain bike and road cycling", Chapter 3, p. 69) of Hamilton Lee, Sport Physiologist (Lee 2003, with permission from 23th May 2006):

"Laboratory studies conducted under constant exercise conditions hardly mimic the conditions encountered by competitive MTB cyclists in the field".

David T. Martin, Senior Sport Physiologist, whom I talked to after his invited speech "Cycling Power Output" at the Endurance Sport Science Conference, Birmingham, UK, 29 – 30 April 2006 (with permission from 18th July 2006), further advocated this choice of design:

"Laboratory testing of athletes can be a useful tool for assessing a number of physiological traits in a controlled condition. In some cases, the laboratory may be useful for establishing maximal performance abilities in a controlled environment that minimizes the influence of technique. However, when physiologists are working with athletes for a long time period in an attempt to improve their fitness for a special event it becomes important to work in the field. It is in the field where sports are really performed, under authentic conditions of training and competition (training–camps, worldcup–races, world championship and so on)."

2.1. Subjects

The recruitment of participants for the examination during the TAC 2004 occurred through the Internet forum of the TAC organizer and was carried out on a voluntary basis. 37 MTB athletes (from 10 nations) competing in the TAC 2004, were recruited for the study. Shortly before the start of this stage race, athletes received information about the mode and schedule of the study, to get familiar with the process of measurement and to simplify the field study itself during the TAC 2004. Written informed consent was obtained after verbal and written explanation of the procedures. The investigation was approved by the Institutional Review Board (Department of Sport Science, University of Innsbruck, Austria) and performed according to the Declaration of Helsinki.

Given the technical and physical difficulties of a TAC, a large number of riders were enrolled in order to reach a sufficient number of MTBers meeting the inclusion criteria. Reasons for exclusion defined using the HR corresponding to the lactate thresholds (LTs). For each cyclist, the HR at a fixed concentration of 2 mmol/L (LT2) and 4 mmol/L (LT4) was determined. In addition, in order to obtain an exercise intensity zone which better reflects very high–demanding efforts, the HR at 6 mmol/L (LT6) was also measured. At and above this level energy supply is increasingly met by anaerobic sources (growing recruitment of type IIa fibres: Gilman 1996, Gilman and Wells 1993).

HR values at LTs were identified by straight line interpolation between the two closest points. From these data, four intensity zones were established to describe the profile of the TAC 2004:

1) LOW zone for intensity below the HR corresponding to LT2
2) MODERATE zone for intensity between the HR corresponding to LT2 and LT4
3) HIGH zone for intensity between the HR corresponding to LT4 and LT6
4) VERY HIGH zone for intensity above the HR corresponding to LT6

2.3. Characteristics of the Transalp Challenge 2004

1074 athletes (537 double teams, within the categories: Men, Masters, Mixed and Women, from nations all over the world) participated in the TAC 2004. The total altitude climbed was 22500 m and the total distance covered by the riders was 662 km. This resulted in a daily average altitude climbed of 2810 m along with a distance of 83 km. The longest uphill climb and downhill section as one unit was 1700 m and 1400 m in altitude difference, respectively. The total distance climbed uphill was 315 km and in downhill section was 275 km. In terms of the daily total load, single stages can be compared to those of the mountainous Vuelta a Espana. As the Tour de France is the ultimate multiple day event for professional road cyclists, the TAC is one of the most difficult XCM races in the world. The drop out rate after eight consecutive stages of competition was 18.81 %, including professional riders.

The characteristics of the TAC 2004 are presented in Table 3. Peak values of temperature and relative humidity were taken from meteorological stations nearest to competitive waypoints of the TAC 2004 (ZAMG, Innsbruck, Austria). In particular, the course profile of Stages 1 to 8 is presented in Figures 2 – 9 in more detail (with permission from 24th October 2007).

Table 2. The three most important tours in road cycling and MTB sports.

Road Cycling	MTB
Giro d`Italia, ITA (May)	Cape Epic, SA (March)
Tour de France, FRA (July)	**Transalp Challenge, BRD/AUT/ITA (July)**
Vuelta a Espana, ESP (September)	Transrockies, USA (September)

2.4. Collection of field data

The daily schedule varies to meet the demands of 1074 MTBers (daily registration, early start time, late finish time, recovery stations, toilets, catering, accommodation, luggage and material transport, medical support, technical support and several more). In the light of several significant operational and organisational difficulties in the participation and completion of this MTB stage race, and due to these huge requirements in the basic conditions and framework of TAC 2004, it was difficult to conduct all the measurements of this field study. After the race, it was not possible to assemble the subjects on their first day of recovery to take a final body water and hematological measurement performed by equilibrated body water pools for understandable reasons, which included meeting their families after eight days of exhausting stage racing, sudden departures on homeward journeys and the immediate onset of vacations.

2.4.1. Questionnaire

Prior to the TAC 2004 athletes had been familiarized with the questionnaire. The 15 graded RPE (rate of perceived exertion) scale (Borg 1998) was used to facilitate the interpretation of HR data in order to quantify exercise intensity. The subjects were instructed to rate how hard the entire stage was by reporting the overall RPE after each individual finish. Smilies were included to rate the status of athletes` mood and fatigue of leg muscles. This additional method of rating was chosen to motivate the subjects to reflect their level of mental and physical exertion. The cyclists were instructed to maintain adequate fluid and nutritional intake (high in carbohydrates). Fluid intake since breakfast and body mass were immediately reported after each individual finish of the daily stages. Body mass was measured including bike uniform but without MTB shoes (Medica, Soehnle, Germany).

2.4.2. Exercise intensity

During the TAC 2004, the HR response was continuously monitored by using short range HR telemetry systems (S710, Polar Electro Oy, Kempele, Finland). The HR was recorded by using a sample rate of 60 s in order to be able to store the HR data of the entire MTB event. At the end of this stage race, all HR files were collected and downloaded. The recorded data was analysed with specific software (Polar Precision Performance 4 SW, Polar Electro Oy, Kempele, Finland) and HR files including more than 5 % of sample data outside a range of 60 – 220 beats/min (bpm) were excluded from the analysis. The relative intensity of exercise was expressed as a percentage of maximum HR reached in each stage (HR_{MAX}Field) and of laboratory determined maximum HR (HR_{MAX}Lab).

2.4.3. Bioelectrical Impedance Analysis (BIA)

The BIA 2000 M multifrequency bioelectrical impedancemeter (Data Input, Hofheim, Germany, NUTRI4 software package) was used to measure the distribution of compartmental body water. An arrangement of four electrodes was applied to the skin after alcohol preparation. The injector electrodes were placed (after users manual) just below the phalangeal–metacarpal joint in the middle of the dorsal side of the right hand and just below the transverse (metatarsal) arch on the superior/upper side of the right foot. Detector electrodes were placed on the posterior side of the right wrist, midline with the prominent pisiform bone on the medial (fifth phalangeal) side and ventrally across the medial ankle bone of the right ankle.

The controlled conditions in this field study suggest the BIA method as to be quite reliable in estimating body water status. After extensive validation, various authors have attested the BIA technique to be reliable in assessing body hydration status under standardized conditions (Buchholz et. al. 2004, Kyle et. al. 2004a+b, O`Brien et. al. 2002, Thomas et. al. 1998)

Baseline measurements of BIA were conducted in the morning before the start of the TAC 2004 between 9 a. m. and 11 a. m. The subjects were asked to avoid exhaustive exercise at least 15 hours prior to this baseline measurement. Post exercise data were respectively determined after 5 min of rest in a relaxed supine position, either immediately or at most up to 10 min after each individual finish of Stages 1, 4 and 6.

Figure 10. BIA measurement post exercise, shown here after Stage 6 at Caldaro/ITA.

2.4.4. Hematological parameters

Blood samples (2 x 10 µL) based on capillary blood from the finger tip were drawn (measurement process was described in Chapter 2.4.3.) to detect Hb and Hct levels (Miniphotometer plus LP 20, Lange, Germany). Robinson et. al. (2005) ratified this method to reliably determine blood parameters in the field in absence of standardized laboratory conditions. Relative changes in PV_{CALC} (Δ%PV) were calculated from pre– and post exercise values of Hb and Hct according to the equation of Strauss et. al. (1951): $\Delta\%PV = 100\times[(Hb_{pre}/Hb_{post})\times(1–Hct_{post}/1–Hct_{pre})]$

Figure 11. Baseline blood measurement is here shown to be drawn prior to the start of the TAC 2004 at Mittenwald/BRD.

2.4.5. Vegan nutrition pattern

Specific recommendations for fluid intake were adopted from Maughan (2002) and Jeukendrup (2002a). Current recommendations for carbohydrate (CHO) intake were adopted (Burke 2002, Hargreaves 2002, Jentjens 2002, Jeukendrup 2002a). Dietary intake was completely recorded over the full period of eight successive days of competition by a 24 hour survey with the maximum possible accuracy. Fluid intake (FI) and energy intake (EI) were calculated for three occasions and subdivided into macronutrients CHO, protein and fat:

1) Pre race (breakfast)
2) Race (sports drink, solid energy bars and energy gels)
3) Post race (including snacks and dinner)

If available, the energy contained in and the composition of packed and/or prepared fluid and food was taken from the producers` declaration. The energy of pieces or portioned food (such as bread or fruit) was calculated. The energy of combined food was derived from detailed information about the ingredients of a specific dish (amount and distribution of macronutrients) and based on personal communication with the respective chefs (standardized portions).

2.5. Statistical analysis

Descriptive data are presented as mean ± standard deviation (SD). After performing the Shapiro–Wilk test, the data was found to be normal distributed. Due to the small sample sizes, non–parametric tests were used for all the analyses.

The differences in average values of RPE, exercise induced FI, HR between the eight stages, and the differences in the time spent within each of the four intensity zones during each stage were examined using the Friedman test and Wilcoxon paired tests as post–hoc analyses. Likewise, the differences in average values of body water compartments between baseline and Stage 1, Stage 1 and 4, and between Stage 1 and 6, were examined using the Friedman test and Wilcoxon paired tests (post–hoc). Analyses were performed by using SPSS software package (version 15.0, Chicago, Illinois, USA). The level of statistical significance was set at $p \leq 0.05$.

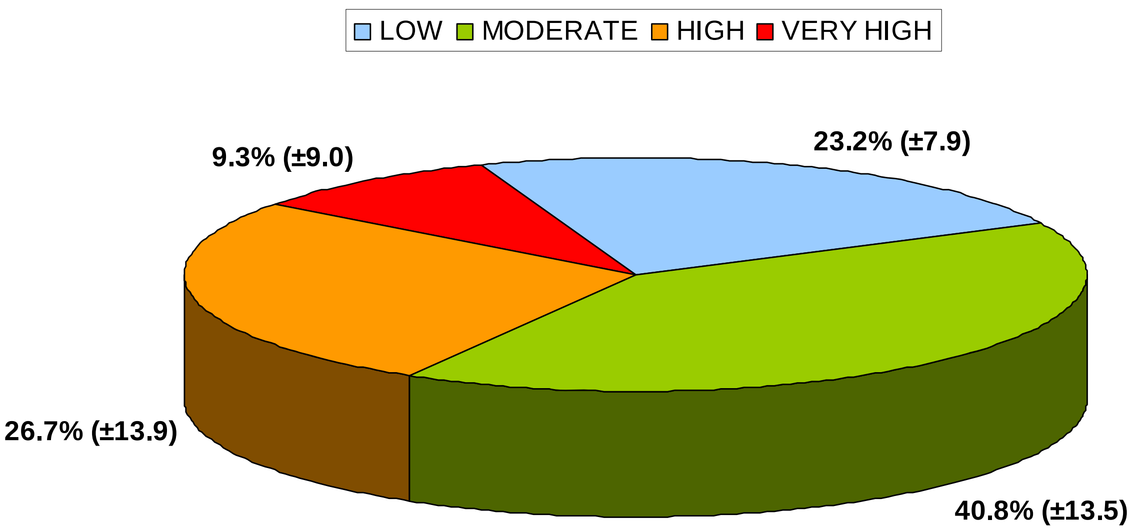
Hematological parameters were analyzed by using SPSS software package, version 11.0 (Chicago, Illinois, USA). Changes in average values of Hb, Hct and PV_{CALC} were examined by paired t test as post–hoc analyses. Correlations were calculated using Pearson`s correlation coefficient (r).

Based on the method of reporting the vegan nutrition pattern, if no food label was available, the calculation of total EI and the respective macronutrients for each piece, portion or dish was calculated using the nutritional information chart of Petter and Pohlmann (2007), besides several standardized food composition databases available online (www.dge.de, www.naehrwerttabelle.de, www.bleibfit.at).

3.2. Exercise intensity

The findings of exercise intensity during the course of the TAC 2004 are presented in Tables 6 and 9 (case study). Figure 13 depicts the distribution of time spent in respective intensity zones. Values were analyzed albeit of gender due to the lack of significance in results of absolute and relative HR between sexes. Pooled data (n=7) of incremental laboratory test show an absolute PPO of 285 (±54) W and relative PPO of 4.5 (±0.5) W/kg. Average maximum HR found in laboratory testing was 177 (±5) bpm. The strikingly high average exercise intensity of 85 % of maximum HR during racing was maintained over the full period of eight successive stages of TAC 2004.

Figure 13. Time spent in respective intensity zones LOW, MODERATE, HIGH and VERY HIGH as determined by $\%HR_{MAX}Field$ (n=7) during the Transalp Challenge 2004. Values are means ± SD.



3.4. Vegan nutrition pattern

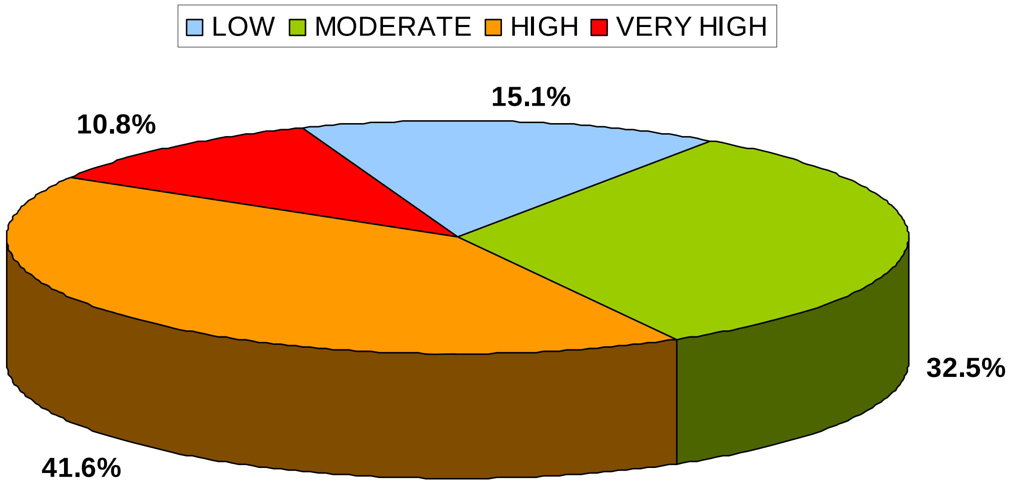
The characteristics of female vegan MTBer is shown in Table 8.

Table 8. Characteristics of the female vegan MTBer and results of incremental laboratory test seven days before the start of the Transalp Challenge 2004 (starting at 100 W, steps of 30 W every 5 min). HR = heart rate, PO = power output, PPO = peak PO, LT = fixed lactate threshold of 2 (LT2), 4 (LT4) and 6 (LT6) mmol/L, bpm = beats/minute.

	Unit	Female MTBer
Anthropological characteristics		
Age	years	30
Body mass (nude)	kg	47
Body mass	kg	50
Height	cm	161
Body mass Index (nude)	–	17.5
Hematological characteristics		
Iron	µg/dl	105
Transferrin	mg/dl	238
Transferrin saturation	%	31
Hemoglobin	g/dl	14
Hematocrit	%	41
Physiological Characteristics		
Absolute PPO	W	230
	W/kg	4.6
PO at LT2	W	174
	W/kg	3.5
	% max	76.1
PO at LT4	W	199
	W/kg	4.0
	% max	87.0
PO at LT6	W	213
	W/kg	4.3
	% max	93.5
Maximal HR	bpm	182
HR at LT2	bpm	154
	% max	84.6
HR at LT4	bpm	166
	% max	91.2
HR at LT6	bpm	168
	% max	92.3

The female vegan MTBer finished the TAC 2004 with an overall runtime of 41 hours 59 min 45 sec, overall achieving 16th rank within the “Mixed” category. She maintained an average exercise intensity of 88 % of HR_{MAX}Field during eight days of successive race during the TAC 2004. The distribution of time spent in respective intensity zones is presented in Figure 15.

Figure 15. Time spent in respective intensity zones LOW, MODERATE, HIGH and VERY HIGH as determined by %HR_{MAX}Field during the Transalp Challenge 2004.

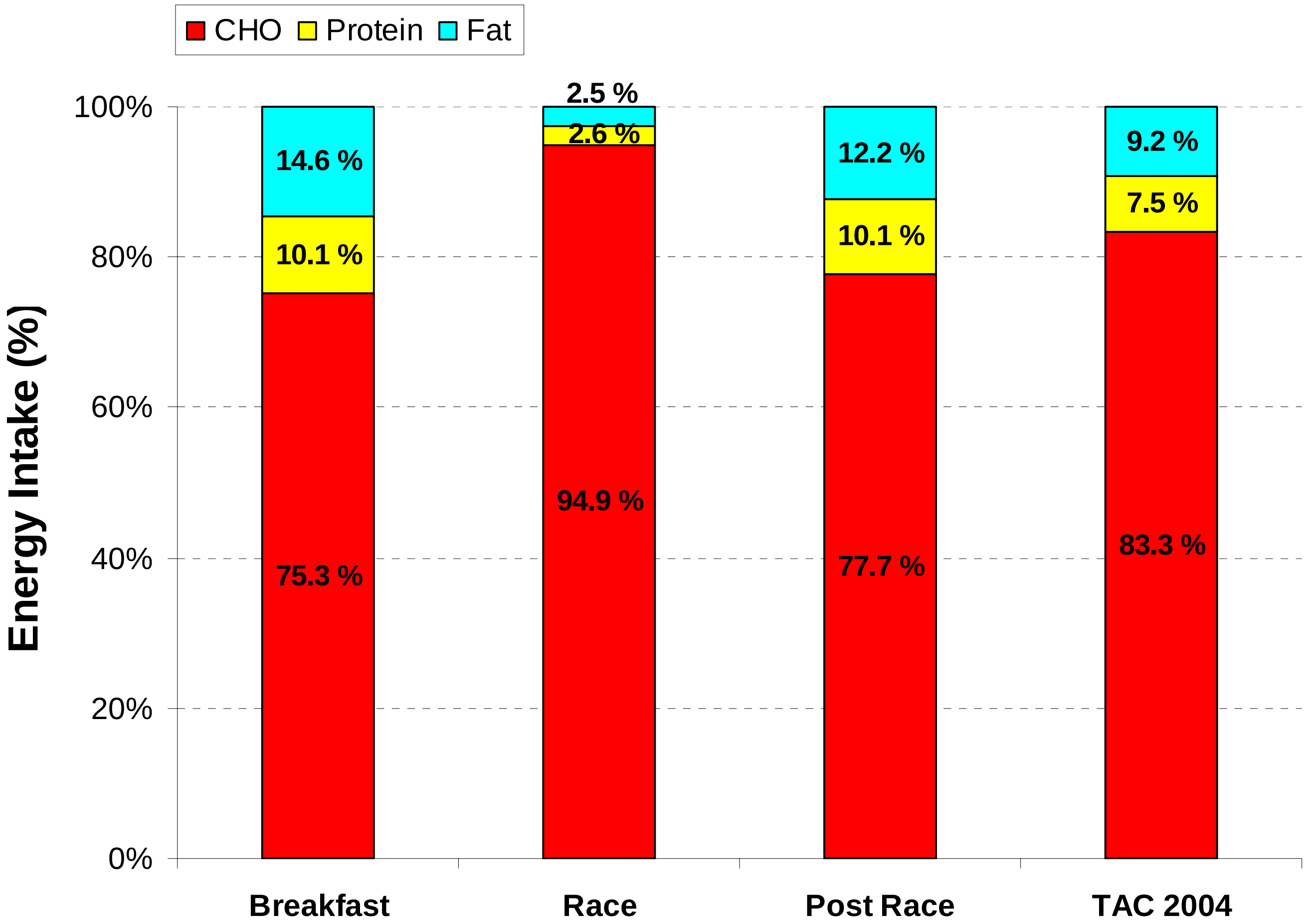


The values of relative fluid and CHO intake during daily racing were calculated to be 12 ml/kg*h and 32 kJ/kg*h, respectively. Additionally, the average daily EI while competing in the TAC 2004 was 24.61 MJ.

When total EI is separated by occasions, the female ingested 17.4 % during breakfast and 35.2 % during racing. The most important occasions to eat were post race, accounting for 47.4 % of total EI. The distribution of total calories was 83.3 % from CHO, 7.5 % from protein and 9.2 % from fat.

During the TAC 2004, the most important food groups were found to be energy food (solid energy bars, gels, drinks) which accounted for 35.2 % (69.3 MJ) of total EI consumed, pizza and pasta together with 17.6 % (34.6 MJ) and snacks and others with 42.9 % (84.4 MJ). Within the latter subgroup, bread played a major role (26.9 %) as well as sweets (6.1 %) and fruit (4.3 %) mainly from bananas.

Figure 16. Macronutrient contribution for each occasion and whole Transalp Challenge 2004. CHO = carbohydrate.



4. Discussion

The focus of this chapter is mainly on the most important factors that might determine, or rather limit, MTB performance while competing in the TAC (for more detailed information see Chapter 7: Peer–reviewed publications in Journal of Sport Science and Medicine (JSSM), European Journal of Applied Physiology (EJAP) and invited book chapter currently to be edited by Novapublishers, New York, USA). The requirements an athlete has to face when participating in the TAC are highlighted by a complex performance capacity, amongst others, including the following aspects:

4.1. Physiological parameters

4.1.1. Physiological profile of the MTB athlete

Considering performance determining factors and physiological profile (Impellizzeri et. al. 2002/2005a+b, Lee et. al. 2002, Stapelfeldt et al. 2004, Wilber et. al. 1997) in MTB sports, a completely different profile of skills and physiological characteristics of the MTB athlete was found in comparison to road cycling. These are due to an enormous peak PO, particularly at the beginning of a race, and a permanent change of load and recovery during the whole event. The individual performance during MTB races is characterized by very high intensities and a very high impact distribution during the whole competition (Impellizzeri et. al. 2002/2005a+b, Stapelfeldt et. al. 2004: 88 – 93 % HR_{MAX} in XC; Wirnitzer 2009, Wirnitzer and Kornexl 2008: 85 – 88 % HR_{MAX} in TAC 2004). On the one hand, the importance of single skills for the MTB performance markedly differs from those for road cycling. On the other hand, the physiologic–anthropometrical characteristics of MTBers are very similar to those of road cycling uphill specialists (Impellizzeri et. al. 2002, Lee et. al. 2002, Prins et. al. 2007, Wilber et. al. 1997). MTBers show a higher relative PPO (W/kg) at maximum load. For example Karl Platt (BRD), professional MTB athlete and 7 times winner of TAC, showed absolute and relative data (maximal aerobic incremental test in spring 2007) of peak PO to be 410 W and 5.86 W/kg (Scheele and Grieshaber 2007).

Success in MTB sports is basically founded on a high power–to–weight ratio (Lee et. al. 2002). Therefore, training programmes should target the improval of relative physiological characteristics rather than the maximization of absolute characteristics to enhance MTB performance (Gregory et. al. 2007, Impellizzeri et. al. 2005a+b, Impellizzeri and Marcora 2007).

Table 11. Development of key data and overall winners` run time of the Transalp Challenge from 1998 to 2008. Parameters significantly correlated (Pearson`s correlation coefficient) to total distance are defined as follows: ° (p=0.003), □ (p=0.01).

Transalp Challenge	Distance (km)	Altitude difference□ (m)	Winners time° (h:min:sec)	Speed (km/h)
1998	595.8	18419	29:32:03	20.2
1999	624.0	20325	28:02:39	21.9
2000	646.1	18249	29:33:44	21.9
2001	668.0	22051	32:05:32	20.8
2002	569.4	19708	26:30:28	21.5
2003	651.3	21520	28:45:19	22.6
2004	662.3	22455	29:21:09	22.6
2005	724.4	22293	32:12:38	22.5
2006	665.0	22572	28:51:55	23.0
2007	628.4	20836	27:32:30	22.8
2008	663.6	21623	29:59:26	22.2
Mean (±SD)	645.3 (±41.0)	20914 (±1560)	29:18:51 (±1:43:37)	22.0 (±0.9)

4.1.3. Prerequisites for the Transalp Challenge

Knowledge of the physiological capacities necessary to successfully participate in MTB events is crucial to develop adequate training strategies and tactics during MTB stage racing.

The current findings demonstrate that a TAC puts a severe impact on the cardiovascular system due to a daily UCI XCM race over eight successive stages. Thus, the training has to be individually planned and consequently conducted both high in extent and intensity. The afore mentioned completely unique profile of skills, physiological characteristics and race induced impact distribution needs to be met by MTB–specific training to cope with all the requirements that an off–road cyclist has to face. Since the TAC is the capital event of the XCM race calendar, some athletes might participate in the TAC only once in their life. Competing in severe MTB stage races might be possible after a minimal training for 4 – 6 weeks, but is not advisable. Therefore, attending at the start of the TAC has to be well prepared and takes time to reach an adequate level of performance to meet this challenge.

The prerequisites to compete in and probably finish a TAC are a high level in both anaerobic and aerobic power and capacity.

Anaerobic power and capacity. MTBing requires both endurance and sprint abilities. Therefore, success in MTB racing is suggested to depend to a large proportion on anaerobic power and capacity (Faria et. al. 2005a, Impellizzeri and Marcora 2007). In order to determine anaerobic ability the athlete is required to generate as much work as possible (seated position, 50 – 140 rpm) during 10 – 30 seconds of isokinetic cycle sprinting (Faria et. al. 2005a). The test most frequently used is the

5. Conclusion

This study was the first to

i) describe the exercise intensity during one of the most important MTB stage races in the world, showing the TAC 2004 to be physiologically very demanding and heavily involving both the aerobic and anaerobic energy system,
ii) study a female MTBer during this difficult multi–day XCM competition and
iii) report the dietary intake during the TAC 2004, showing a well planned vegan diet to adequately meet the nutritional demands of severe MTB stage racing.

The current findings might be useful to design specific training programs and to develop appropriate nutritional strategies to sustain the physical demands of severe XCM and MTB stage races. Therefore, prospective research should aim to focus on one day MTB XCM and MTB stage events, female off–road cyclists as well as vegetarian and vegan dietary patterns and their influence on endurance performance, particularly on high performance (road and off–road) cycling and stage racing.

and energy intake (EI) were calculated and subdivided into macronutrients carbohydrate (CHO), protein and fat.

Results. The exercise intensity of 88 ± 2 % of HR_{MAX} determined in the field was maintained over eight days. EI was found to be 24.61 MJ/day. Total calories contribute to 83.3 % from CHO, 7.5 % from protein and 9.2 % from fat. The female ingested 17.4 % pre–race, 35.2 % while racing and 47.4 % post–race.

Discussion. This was the first study showing a well planned vegan diet to adequately meet the nutritional demands of severe MTB stage racing. The dietary requirements of a TAC are challenging for several reasons. Opportunities and time available for FI and EI are restricted by a great diversity of terrains and traits (difficult nature of course profile) simultaneously with aggressive riding tactics. After many years of research, mainly focused on health aspects, the effects of a plant–based diet on athletic performance are still unclear. However, any athlete, regardless of whether omnivore or vegan, should plan his/her diet carefully to avoid the risk of nutritional deficiencies and adverse effects on performance. It is broadly accepted that athletes involved in heavy endurance exercise should ingest a higher amount of energy from CHO to maximize muscle glycogen synthesis. The main advantages of vegetarian diets are the higher amount of CHO, lower fat and adequate protein. Especially vegans consume the majority of their energy from CHO. Therefore, endurance athletes may adopt vegetarian diets as an optimum strategy. Generally, endurance training and competition tend to reduce iron stores. However, iron deficiency occurs in 20 % of the world population, reflecting a similar incidence among vegetarians or vegans compared to omnivores.

Introduction

Protein – a historical review. In 1839 the Dutch chemist Gerhard Mulder discovered the nitrogen–containing chemical substance protein (Greek: proteios, "of premium importance"). Early scientists such as the German Carl Voit were staunch advocates of protein. He stated that "man" cannot get too much protein. Voit was the mentor of several nutritional scientists in the early 1900s, such as W. O. Atwater (organizer and director of the first nutrition laboratory at the United States Department of Agriculture/USA). The British physician Major McCay was stationed in the colony of India (1912). By identifying good fighting men in the Indian tribes, he commented that people who consumed less protein were found to be of worse physique (Campbell and Campbell 2006).

To date, protein is still the most misunderstood and misinterpreted of all nutrients. In the nineteenth century protein was synonymous with animal protein. Protein was, and today still is, equated with meat. The vital force was suggested to be exclusively inserted into meat. Therefore, the people were encouraged to eat as much meat as possible. The belief in this connection is still held by many people. Most people immediately think of meat, when they consider protein. That is why vegetarians and vegans still have to face the question of how they will obtain their protein requirements, because plant based protein is even thought to be execrable (Campbell and Campbell 2006).

Following the accumulated scientific knowledge of former times, someone ate plenty of protein (meat), if he/she was civilized and rich. When a person was poor and belonged to the lower social classes, they ate plant based foods such as potatoes and bread. They were considered to be indolent and less capable, as a result of not eating sufficient amounts of animal protein. As a consequence, this leaded to a fundamental cultural bias that had become firmly entrenched (Campbell and Campbell 2006).

Scientific studies considering plant based nutrition connected to sports. The relationship between nutrition and exercise has been a major area of scientific interest for over 150 years (Febbraio 2002).

In the late 1800s the London Vegetarian Society formed an athletic and cycling club to compete against their meat eating counterparts which outperformed them in most cases during athletic competition (Niemann 1988). In 1893 such a cycling race was conducted from Berlin to Vienna (599 km) in which the first two finishers were vegetarian (Whorton 1982).

At the beginning of the 20th century, Russell H. Chittenden, a well established scientist in the field of nutrition at the Yale University Medical School, studied whether the consumption of plant based diets influences physical capacities. The physical performance of the male subjects (students, fellow faculty members, himself) was measured during laboratory testing. He found that ingesting a plant based diet enables the subject to exercise more, with less fatigue, compared with a diet based on animal protein (Chittenden 1904/1907). Simultaneously and also at Yale, Irving Fisher (having a wide range of interests including diet and nutrition) designed a series of tests to compare the stamina and strength of meat–eaters against those of vegetarians. Male subjects were selected from three groups: meat–eating athletes, vegetarian athletes and vegetarian sedentary subjects. The results have shown that vegetarians have twice the stamina of meat eaters, showing the latter to have far less endurance than the vegetarians (even in sedentary subjects). He reasoned that the difference in endurance was entirely due to the difference in their diet. He provided strong evidence that a vegetarian diet raises endurance (Fisher 1907).

In 1968, a Danish team of researchers re–popularized Fishers classic Yale study. A variety of diets were tested on male subjects by using a stationary bicycle to measure their strength and endurance. First, the men were fed a mixed diet of meat and vegetables for a period of time, and then tested on the bicycle. The average time they could pedal before muscle failure was 114 minutes. Later, they were fed a diet rich in meat, milk and eggs for a similar period and were then re–tested. On the high animal protein diet, their pedalling time dropped dramatically to 57 minutes. Finally, the group was switched to a strictly vegetarian diet, composed of grains, vegetables and fruits. Following a diet lacking in animal products, they pedalled for an average of 167 minutes (Astrand 1968).

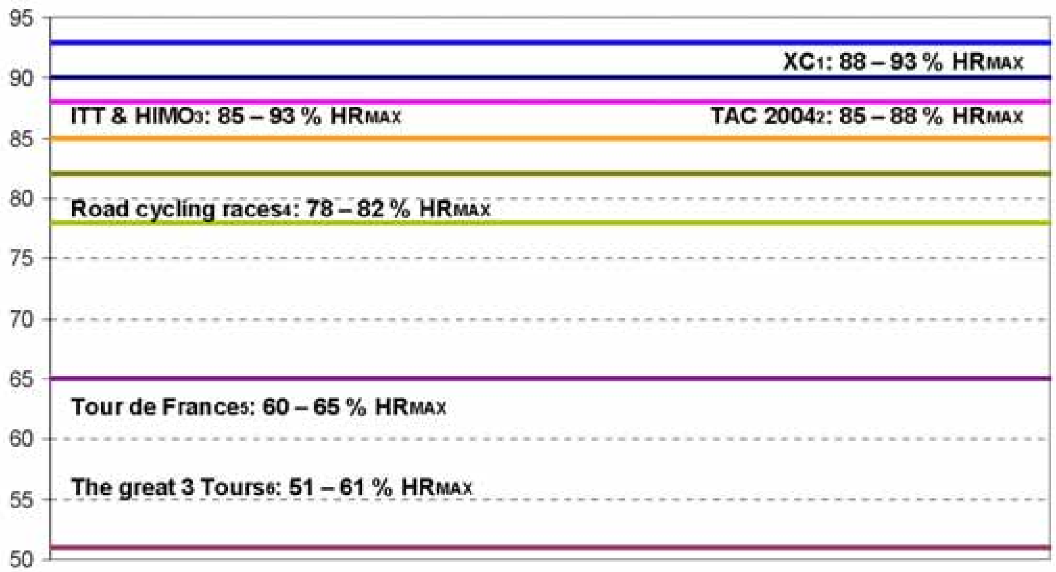
Growing interest in vegetarian diets. Since the 1960s, there has been a growth in professional interest in vegetarian nutrition. As shown in Figure 1, the number of articles in the scientific literature related to vegetarism has increased (Sabate et. al. 1999). Additionally, the main focus of the articles is changing. In the late 1960s, articles primarily tended to question the nutritional adequacy of vegetarian diets. More recently, the predominant issue has been the use of vegetarian diets in the prevention and treatment of chronic disease. There is a growing appreciation of the clear benefits of plant–based diets (Campbell and Campbell 2006, ADA 2003).

In 1978, the earliest major report on five studies which measured the diets of a cohort of individuals and monitored their subsequent death was published. It compared disease mortality in pure vegetarians (vegans) with that in other vegetarians and meat–eaters. The results showed the vegans to have had the lowest rates of mortality due to heart disease. Along with other studies, this confirmed the vegetarian diets to be beneficial against heart disease (Phillips et. al. 1978).

Figure 1 Development of scientific interest in vegetarian nutrition, showing the number of articles published per year, drawn from Chittenden (1904/1097), Fisher (1907) as well as Sabate et. al. (1999).

HR_{MAX} = maximum HR, ITT & HIMO = individual time trial & high mountain stages (road cycling races).

[1](Impellizzeri et. al. 2002/2005a+b, Stapelfeldt et. al. 2004), [2](Wirnitzer and Kornexl 2008), [3](Lucia et. al. 2003, Palmer et. al. 1994), [4](Palmer et. al. 1994), [5](Saris et. al. 1989), [6](Padilla et. al. 2001)



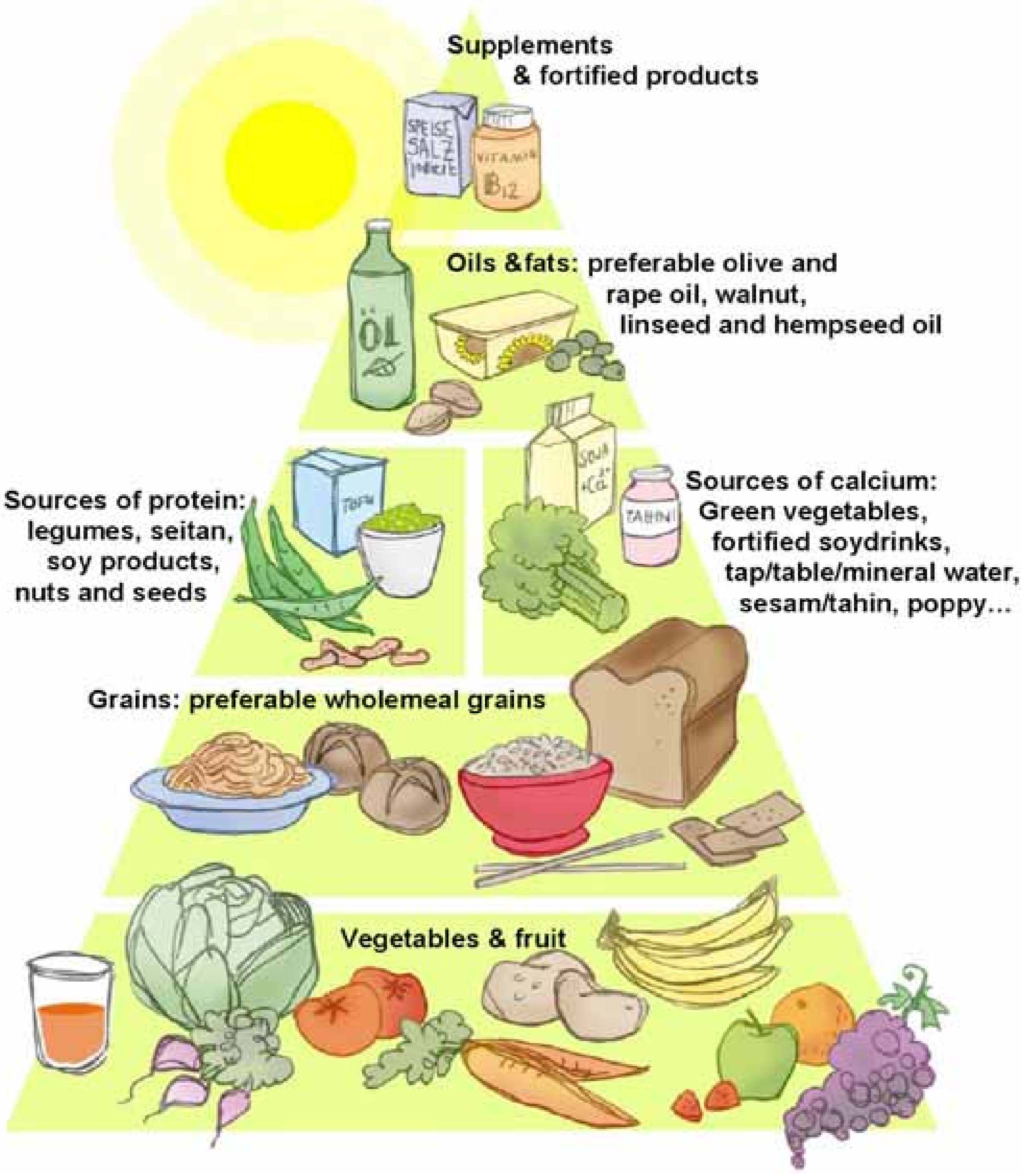
Racing in the heat. When exercising in the heat as well as endogenous heat is produced, thermoregulatory mechanisms of the body are heavily stressed by heat loss. As a result fatigue prior to CHO depletion occurs. Therefore, fluid ingestion is of major importance in order to postpone a rise in body core temperature and to prevent impaired exercise performance resulting from several factors (Febbraio 2002). Any athlete who is exposed to heat may require different levels of some nutrients from those recommended by current guidelines (Knechtle et. al. 2005). It is generally accepted that exercise in the heat results in a substrate shift towards increased CHO utilization (Febbraio 2002).

FI not only attenuates the rise in body core temperature, it also reduces the likelihood of CHO depletion by reducing the muscle glycogen use during prolonged exercise (Hargreaves et. al. 1996a+b). Together, both CHO and fluid availability are vital when exposed to heat during severe exercise and result in an improved exercise performance in a hot environment (Febbraio 2002, Below et. al. 1995). Therefore, especially during racing, it is mechanism to improve cycling performance by CHO ingestion might be also the resynthesis of muscle glycogen during periods of low intensity (Jeukendrup 2002a, Hargreaves et. al. 1984).

In the current study, an intake of 1195 g/day came from CHO. Compared to Martin et. al. (2002), who reported a CHO intake of 588 g/day during a race period of five days, the result of the MTBer is about twice the value of that for female road cyclists. Erp van–Baart et. al. (1989), studying amateur cyclists in the Tour l`Avenir reported a daily intake of 873 g from CHO. Almost a decade later, Garcia–Roves et. al. (1998) found a similar CHO intake during the Vuelta a Espana (841.4 g/day). Currently recommended energy from CHO for a more competitive woman participating in endurance and ultra endurance events had been given as 55 – 70 % of total intake (Gabel 2002). The total calories coming from CHO during TAC 2004 (83.3 %) exceed the advocated range by about 13.3 %. Relative CHO intake (24.4 g/kg*day) is twice as high as the recommendations of 8 – 12 g CHO/kg*day (Jentjens 2002, Jeukendrup 2002a) and more than twice the guidelines for female athletes of 6 – 10 g CHO/kg per day (Gabel 2002).

Dietary intake in vegan athletes. The vegan diet is determined to be exclusively sourced from plant based nutrition, rejecting all products from animal sources (as one unit, ingredient or supplement) such as meat, fish, dairy products, egg and honey (see Figure 12).

Figure 12 Vegan nutrition pyramide after Petter and Pohlmann (2007: with permission).



The European Union currently has 1.73 % of its population (6.72 million people) following a vegetarian or vegan lifestyle (representative survey conducted by the European Commission: http://ec.europa.eu/food/animal/welfare/euro_barometer25_volA_en.pdf). A UK wide survey carried out by the Food Standards Agency (Consumer Attitudes to Food Standards 2007: www.vegsoc.org/info/statveg.html) in 3513 adults found 2 % of respondents to be "completely vegetarian". The number of vegans in the UK is estimated to be at around

0.3 % of the population (180,000 people: www.imaner.net/panel/statistics.htm). Further reliable information based on the available research (Dietary Habits of Adults 18 and Older in the United States) puts the figure ranging from 0.5 % – 1.4 % of the USA population to be vegan, with the possible exception of honey (2008: www.imaner.net/panel/statistics.htm, 2006: www.vrg.org/journal/vj2006issue4/vj2006issue4poll.htm).

In general, vegetarians are known to be more "health conscious" than non–vegetarians (Bedford and Barr 2005). To date, the female MTB athlete has successfully followed a vegan lifestyle since 1999 and thus has gained previous experience.

According to the meta–analysis of the ADA (2003), a vegetarian – including vegan – diet can meet current recommendations for all nutrients. A well planned vegan and other type of vegetarian diet is appropriate for all stages of the life cycle, including during pregnancy, lactation, infancy, childhood and adolescence. Vegetarian diets offer a number of nutritional benefits as well as higher levels of CHOs.

"It is the position of the American Dietetic Association and Dietitians of Canada that appropriately planned vegetarian diets are healthful, nutritionally adequate, and provide health benefits in the prevention and treatment of certain diseases" (ADA 2003). Together, these advantages include lower risk for heart disease, blood cholesterol levels, blood pressure, hypertension, diabetes mellitus, obesity and some types of cancer (Kugler 2007, Campbell and Campbell 2006, Venderly and Campbell 2006, ADA 2003).

After many years of research, mainly focused on issues connected to health (nutritional adequacy and the implications for diseases of affluence) rather than on human performance issues, the effects of a plant based diet on athletic performance are still unclear. Little is know about the relationship between vegetarianism and athletic performance even today, in spite of the popular belief that these kinds of diet may be beneficial to some athletes. Thus, there is a certain lack of information relating to veganism and its relationship to endurance performance. All athletes at some time in their career look at alternative eating patterns in the effort to reach their full athletic potential. While some take pills and/or powders, others have changed their nutritional styles to a vegetarian diet to gain advantages in training and enhance performance (Berning 2002).

However, any athlete, regardless of whether omnivore or vegan, should plan his/her diet carefully to avoid the risk of nutritional deficiencies and adverse effects on performance (Venderly and Campbell 2006, Berning 2002). There is sufficient evidence from laboratory and field that a well planned vegetarian or vegan diet can meet the energy and nutrient

A.2. List of scientific activities

A.2.1. List of publications

1. **Wirnitzer KC (2005)** Athletic performance capacity in mountainbike sports under extremely strenuous more days lasting endurance impact – Performance–determining and performance–limiting factors during the hardest mountainbike race in the world. In: Kotli, K. Young European in Science. Prague: 113–121
2. **Wirnitzer KC (2005)** Athletic performance capacity in mountainbike sports under extremely strenuous more days lasting endurance impact, in: Proceeding Book – 4th International Scientific Conference of Kinesiology, Science and Profession – Challenge for the Future. Opatija, Croatia: 491–495
3. **Wirnitzer KC (2005)** Hemoglobin and hematocrit in mountain bike sports under extremely strenuous more days lasting endurance impact. In: Programme and Book of Abstracts – International Congress Mountain and Sports, Updating Study and Research from Laboratory to Field. Rovereto: 56
4. **Wirnitzer KC (2006)** Hemoglobin and hematocrit in mountain bike sports under extremely strenuous more days lasting endurance impact. In: Abstract Booklet (8–9), BASES Inaugural Cycling Interest Group in Association with the 1st World Conference of Science in Cycling, University of Birmingham on 29th/30th April 2006 (www.endurancesportscience.com/index.html): Abstract booklet available online from URL: www.bases.org.uk/newsite/cyclingsig.asp, www.bases.org.uk/newsite/pdf/Abstract%20book%20etc.pdf
5. **Wirnitzer KC and Faulhaber M (2007)** Hemoglobin and hematocrit during an 8 day mountainbike race: a field study. Letter to the Editor. Journal of Sports Science and Medicine 2007;6 (serial online), available from URL: http://www.jssm.org/vol6/n2/16/v6n2–16text.php
6. **Wirnitzer KC and Kornexl E (2008)** Exercise intensity during an eight–day mountain bike marathon race. Eur J Appl Physiol Dec;104(6):999–1005
7. **Wirnitzer KC (2009)** Nutrition strategy during an eight–day mountainbike stage race – a case study. Vegan nutrition pattern of a female mountainbiker. Invited Book Chapter by Novapublishers, New York, USA. In: "Aerobic Exercise: Types, Duration and Health Benefits." Acceptance for publication confirmed on 18th February 2009.

A.2.2. Participation and speeches at scientific conferences

1. **Prague, Tschechoslovakia (2005)** Young European in Science Conference
2. **Optaija, Croatia (2005)** 4th International Scientific Conference of Kinesiology, Science and Profession
3. **Rovereto, Italy (2005)** International Congress Mountain and Sports
4. **Birmingham, United Kingdom (2006)** 1st World Conference of Science in Cycling
5. **Vienna, Austria (2008)** 3rd International Animal Rights Congress

A.2.3. Scientific award and researchers grant

1. **Prague, Tschechoslovakia (2005)** Young Researcher Award, ranked 2nd within the catagory “Sport Training”
2. **Innsbruck, Austria (2006)** Researcher Grant of the Leopold–Franzens University of Innsbruck (granted by the Principal of the University of Innsbruck, Austria, Manfried Gantner)

Berchat 302/2
A – 6135 Stans
+ 43 (650) 590 17 94
katharina@wirnitzer.at

Mag. rer. nat. Katharina Wirnitzer

Persönliche Daten	Geboren am 14. Februar 1974 Verheiratet seit Oktober 1999
Beruflicher Werdegang	1980 – 1984 VS Mutters und Wattens 1984 – 1988 WRG der Ursulinen in Innsbruck 1988 – 1993 HBLA für wirtschaftliche Berufe in Innsbruck WS 1993 Beginn Studium Sportwissenschaften, Studienzweig Leibeserziehung an der Universität Innsbruck SS 1995 Studium Sportwissenschaften an der Deutschen Sporthochschule Köln WS 1995 Beginn Studium Physik, Studienzweig Lehramt an der Universität Innsbruck Sommersaison 1996 Geschäftsführung & Paragliding–Instructor, Flugschule Kössen Sommersaison 1997 bis 2000 Paragliding–Instructor, Flugschule Wildschönau Sommersaison 2000 Aufbau, Geschäftsführung & Paragliding–Instructor, Flugschule Achensee als Tochter–Unternehmen der Flugschule Wildschönau 10/2000 – 10/2001 Projektleitung mit abschließender Podiumsdiskussion zum Thema „Wissenschaft und Verantwortlichkeit in der Medizin“

	WS 2001 bis SS 2002 Diplomarbeit im Studienfach Physik „Physik des Fliegens – Geschichte, didaktische Aufbereitung und Demonstrations–Experimente“, betreut von Univ.–Prof. Dr. Armin Denoth & Studienabschluss im Studienfach Physik an der Naturwissenschaftlichen Fakultät der Universität Innsbruck (7. Juni 2002) SS 2004 Projektstart „bikeextreme“ am 1. April 2004 im Rahmen meiner Dissertation „Athletic performance capacity in Mountainbike Sports under extremly strenuous more days lasting endurance impact – Performance–determining and perfomance–limiting factors during the Transalp Challenge“ WS 2004 Studienbeginn für das Doktorat der Naturwissenschaften, Fachgebiet Sportwissenschaft, betreut durch Univ.–Prof. DDr. Martin Burtscher 2002 – 2003 Lehrtätigkeit am BRG/BORG Wörgl 2003 – 2005 Lehrtätigkeit am BRG/BORG Schwaz Seit 2005 Lehrtätigkeit an der BHAK/BHAS Wörgl, seit 9/2007 Leitung Fachbereich Sport & Bewegung, seit 9/2008 Koordinatorin für den Aufbau der neuen Fachrichtung „Sport– & Eventmanagement“ mit Beginn Schuljahr 2009/10 Seit 2006 Hochschullehrgang Ethik (Postgradualer Lehrgang zur Erlangung der Lehrbefähigung Ethik. ECTS: 80) an den Pädagogischen Hochschulen Tirol und Vorarlberg WS 2008/09 Abschluss des Doktoratstudiums am 28. April 2009