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No Improvement in Race Performance by Naps in Male Ultra-Endurance Cyclists in a 600-km Ultra-Cycling Race

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Abstract

Ultra-endurance performance is of increasing popularity. We investigated the associations between anthropometry, training and support during racing, with race performance in 67 male recreational ultra-endurance cyclists participating in the 'Swiss Cycling Marathon' over 600 kilometres, an official qualifier for the cycling ultra-marathon 'Paris-Brest-Paris'. The 54 finishers showed no differences in anthropometry and did not train differently compared to the 13 non-finishers. During the race, the finishers were significantly more frequently racing alone than being followed by a support crew. After bivariate analysis, percent body fat (r = 0.43), the cycling distance per training unit (r = -0.36), the duration per training unit (r = -0.31) and the sleep time during the race (r = 0.50) were related to overall race time. The 23 non-sleepers in the finisher group completed the race within (mean and IQR) 1,567 (1,453-1,606) min, highly significantly faster than the 31 sleepers with 1,934 (1,615-2,033) min (P = 0.0003). No variable of support during the race was associated with race time. After multivariate analysis, percent body fat (P = 0.026) and duration per training unit (P = 0.005) remained predictor variables for race time. To summarize, for a successful finish in a cycling ultra-marathon over 600 kilometres such as the 'Swiss Cycling Marathon', percent body fat and duration per training unit were related to race time whereas equipment and support during the race showed no association. Athletes with naps were highly significantly slower than athletes without naps.

Key Words: training, support, anthropometry, performance, sleep

Introduction

Literature on ultra-endurance cycling is relatively small and focusing in case reports (16, 21) and small case series (11) primarily on nutrient intake and energy turnover. Considering the aspect of variables associated with a successful finish in an ultra-cycling performance, body fat percentage was related to race performance in a 600-km cycling ultra-marathon in a recent field study on recreational male ultra-endurance cyclists (19). Apart from body fat, body mass might also be related to race performance in cyclists as has been described for both road cyclists (33) and mountain bikers (6, 12, 13) over shorter distances. In addition to anthropometric and training characteristics, however, other factors such as equipment (25) and motivation (14) might influence race outcome in an ultra-endurance performance.

While the 'Race across America' (RAAM) is the most famous ultra-cycling race in America (11, 16, 21, 30) (www.raceacrossamerica.org), the ultra-cycling marathon 'Paris-Brest-Paris' (www.paris-

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brest-paris.org) is the most famous non-stop ultra-cycling race for recreational ultra-cyclists in Europe. 'Paris-Brest-Paris' is an ultra-cycling marathon over ~1,200 km with ~10,000 m of altitude to cover and takes place every four years. Participants in 'Paris-Brest-Paris' can be followed by a support crew and choose to finish the 1,200 km within 90 h, 84 h or 80 h. Cyclists intending to participate in 'Paris-Brest-Paris' have to complete qualifying races over the distances of 200 km, 300 km, 400 km and 600 km.

The aim of the present study was to investigate associations between anthropometry, training and race support with total race time in order to find predictor variables for race performance in a 600 km-qualifier for 'Paris-Brest-Paris'. We investigated in the 'Swiss Cycling Marathon' (www.radmarathon.ch) ultra-cyclists intending to qualify for 'Paris-Brest-Paris'. We assumed that apart from anthropometry, training and nutrition, other factors such as support during the race and equipment would show an association with race time.

In a very recent case report from the 'RAAM', the aspect of sleep and riding time was investigated. Regular recovery and sleep were considered as an alternative strategy to successfully finish an ultra-cycling race (30). Sleep deprivation may lead to impaired perception, difficulties in keeping concentration, vision disturbances, slower reactions, as well as the appearance of micro-episodes of sleep during wakefulness which lead to lower capabilities and efficiency of task performance and to an increased number of errors (26). Reaction time becomes significantly slower after sleep deprivation. This could result in a greater risk of accident due to a reduced capacity to respond quickly (32).

Respecting existing literature on ultra-endurance cycling, we hypothesized that [1] variables of both anthropometry and training would be related to race performance, to find [2] a relationship between equipment and support during the race with race time and that [3] athletes with naps might be faster than athletes without naps.

Materials and Methods

Subjects

The 'Swiss Cycling Marathon' (www.radmarathon.ch) takes place every year and offers, apart from the shorter distances, a 600 km loop in order to qualify for 'Paris-Brest-Paris'. Since only a small number of athletes participate in ultra-endurance races (18, 19), we collected data in two subsequent years, the 2009 and 2010 events, in order to increase the sample size. The organiser of the 'Swiss Cycling Marathon' contacted all the race participants *via* monthly newsletters and provided them the information about the planned investigation. Interested athletes contacted the investigator by e-mail and were provided with the study documentation. A total of 67 athletes in these two 'Paris-Brest-Paris'-qualifiers were interested in our study. Athletes competing in both years were included upon their first participation. They all gave their informed written consent. The study was approved by the Ethical Committee of Canton St. Gallen, Switzerland.

The Race

The 'Swiss Cycling Marathon' takes place at the end of June/start of July. In the 600 km race, the athletes have 10 check points to pass and must cover a total altitude of ~4,700 m. The 600 km loop starts from the outskirts of Berne (Switzerland) over the border to Germany, then along Lake Constance into the Alps of Eastern Switzerland and back to Berne. Weather conditions were comparable in both years. In the 2009 event, the weather in Berne was fine and sunny at ~22°C during the day and ~11°C in the night. In the 2010 race, the temperature rose to ~25°C and dropped to ~9°C. In both years, there was no rain.

Measurements and Calculations

Upon entering the study at the time of inscription to the race, the athletes kept a comprehensive training diary, recording their training units in cycling, showing the distance in km, the duration in min and the speed in km/h for each training session, until the start of the race. Pre-race, the weight of the race bike was determined without additional equipment. Before the start of the race body mass, body height, circumferences of limbs such as upper arm, thigh and calf and thicknesses of skin-folds at pectoral, mix-axilla, triceps, supscapular, abdominal, suprailiacal, front thigh and medial calf site were measured on the right side of the body. Body mass was measured using a commercial scale (Beurer BF 15, Beurer, Ulm, Germany) to the nearest 0.1 kg. Body height was measured using a stadiometer to the nearest 1.0 cm. The circumferences of the limbs were measured using a non-elastic tape measure (cm) (KaWe CE, Kirchner and Welhelm, Germany). The circumference of the upper arm was measured at mid-upper arm, the circumference of the thigh was taken at mid-thigh and circumference of the calf was measured at mid-calf. The skin-fold data were obtained using a skin-fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zürich, Switzerland) and recorded to the nearest 0.2 mm. The skin-fold measurements were taken once for all eight skin-folds and then the procedure was repeated twice

Table 1. Comparison of anthropometric variables between finishers and non-finishers

	Finisher (n = 54)	Non-Finisher (n = 13)
Age (y)	46.0 (40.0-50.0)	45.0 (40.7-50.0)
Body height (cm)	1.81 (1.77-1.85)	1.76 (1.70-1.84)
Body mass (kg)	78.3 (71.9-84.3)	75.4 (69.3-87.4)
Body mass index (kg/m^2)	24.5 (22.3-26.0)	24.5 (22.5-27.6)
Percent body fat (%)	17.1 (14.1-19.3)	18.1 (14.9-21.1)
Skeletal muscle mass (kg)	39.0 (35.9-42.0)	39.0 (36.0-42.0)

Values are given as median (IQR). No differences were found between finishers and non-finishers.

more by the same investigator; the mean of the three times was then used for the analyses. The timing of the taking of the skin-fold measurements was standardised to ensure reliability. According to Becque *et al.*, readings were performed 4 s after applying the calliper (2). One trained investigator took all the skin-fold measurements as inter-tester variability is a major source of error in skin-fold measurements. An intra-tester reliability check was conducted on 27 male runners prior to testing. Intra-class correlation (ICC) within the two judges was excellent for both men and women for all anatomical measurement sites (ICC > 0.9) (17). Percent body fat was estimated using the anthropometric formula according to Ball *et al.* where percent body fat = $0.465 + 0.180 \times \Sigma 7SF - 0.0002406 \times \Sigma 7SF^2 + 0.0661 \times age$, with $\Sigma 7SF$ = sum of skin-fold thickness of pectoral, mix-axilla, triceps, supscapular, abdominal, suprailiacal and front thigh (1). Skeletal muscle mass was estimated using the anthropometric formula according to Lee *et al.* where skeletal muscle mass = $Ht \times (0.00744 \times CAG^2 + 0.00088 \times CTG^2 + 0.00441 \times CCG^2) + 2.4 \times sex - 0.048 \times age + race + 7.8$ with Ht = height, CAG = skin-fold-corrected upper arm girth, CTG = skin-fold-corrected thigh girth, CCG = skin-fold-corrected calf girth, sex = 1 for male, race = 0 for white (20). After the race, the finishers were asked whether they had completed the race alone or with the help of a support crew, whether they had followed the signposts set by the organiser or used GPS (Global Positioning System), whether they had carried their own equipment to mend a flat tyre or whether they had spare parts or a complete replacement bike with them in their support car, and whether they had used the nutrition provided by the organiser at the check points or whether they had used their own nutrition. In addition, they reported whether they took a break for sleep and, if so, stated the time invested in sleeping.

Statistical Analysis

Data were checked for normal distribution. Non-normally distributed data were presented as mean and interquartile range (IQR). Race times in 2009 and 2010 were compared using Wilcoxon signed-rank test. Variables of anthropometry and training between finishers and non-finishers were compared using Wilcoxon signed-rank test. Fisher's exact test was applied for categorical data to assess the association between nutrition and equipment with race time. Race time was also expressed as a percentage of the course record (19:03 h:min for the 600 km). Correlation analysis was performed using variables of anthropometry, training and race support with race time in order to reduce the variables for a multivariate analysis. Variables with significant association in the bivariate analysis entered the regression model. Multivariate analysis was then used to determine the best variables correlated with overall race time. An alpha level of 0.05 was used to indicate significance.

Results

Race times were not different between finishers in 2009 and 2010. Sixty-seven participants started in the 'Swiss Cycling Marathon' as 'Paris-Brest-Paris'-qualifier and 54 participants (80%) finished. Among the 13 unsuccessful 'Paris-Brest-Paris'-qualifiers, one athlete stopped because of continuous vomiting, one athlete complained about cardiac arrhythmia, one athlete had a problem with the chain on his bike and the other 10 gave up due to exhaustion with no further specification.

The athletes completed the 600 km within 1,624 (1,516-1,989) min, cycling at a speed of 22.2 (18.1-23.7) km/h and finished within 142 (132-175) % of the course record. The 54 finishers showed no differences in anthropometry compared to the 13 non-finishers (see Table 1). As regards to training, the finishers trained no differently compared to the non-finishers (see Table 2). Twenty-one of the finishers had completed 2.0 (1.0-3.3) 'Swiss Cycling Marathons', whereas no non-finisher had completed such a distance before. Regarding support during the

Table 2. Comparison of variables of training and pre race experience in finishers and non-finishers

	Finisher (n = 54)	Non-Finisher (n = 13)
Years as active cyclist	11.5 (8.0-20.1)	9.0 (7.0-10.3)
Kilometres covered in the year before race	9,160 (6,093-11,483)	9,861 (3,250-15,124)
Number of training units in cycling per week	3 (2-4)	3 (2-4)
Minimal cycling distance per training unit (km)	50 (30-60)	55 (37-60)
Maximal cycling distance per training unit (km)	200 (178-280)	250 (200-266)
Mean cycling distance per training unit (km)	80 (75-100)	90 (70-117)
Mean duration per training unit (min)	205 (150-240)	180 (140-215)
Mean speed per training unit (km/h)	27 (26-29)	28 (25-29)
Mean weekly distance in cycling (km)	275 (210-360)	280 (250-400)
Mean weekly duration of training (h)	10.5 (7.5-12.0)	9.0 (7.2-17.8)
Number of finished 'Swiss Cycling Marathons'	2.0 (1.0-3.3) * (n = 21)	0

Values are given as median (IQR). *: $P < 0.05$.

Table 3. Comparison of equipment and support during the race between finishers and non-finishers

	Finisher (n = 54)	Non-Finisher (n = 13)
Weight of the race bike (kg)	8.8 (8.0-9.8)	8.0 (7.8-9.9)
Racing alone	41*	6
Racing with support crew	13	7
Racing following signpost set by organiser	45	11
Racing following GPS	9	3
Racing with tubes and pump	45*	6
Racing with complete replacement bike	9	7
Racing using nutrition provided by organiser	48	5
Racing using own nutrition	26	8
Rest with sleep (min)	80 (30-175) (n = 31)	200 (133-233) (n = 3)

Values are given as median (IQR). *: $P < 0.05$.

race, the finishers were significantly more frequently cycling alone than followed by a support crew compared to the non-finishers (see Table 3), and they carried their own equipment with them to mend a flat tyre rather than relying upon a support crew with equipment.

Thirty-one finishers (57%) took a break for sleep; three non-finishers (23%) also took a rest for sleep. Of the 31 finishers taking a break, three athletes took more than one break to sleep. The 23 non-sleepers in the finisher group completed the race within 1,567 (1,453-1,606) min, highly significantly faster than the 31 sleepers with 1,934 (1,615-2,033) min ($P = 0.0003$) (see Fig. 1). Percent body fat (see Table 4), the average cycling distance per training unit and the average duration per training unit (see Table 5) were related to race time after bivariate analysis. No variable of support during the race was associated with race time (see Table 6). Time spent in sleeping during the race was significantly and positively related to race time (see Fig. 2).

When all variables with significant association

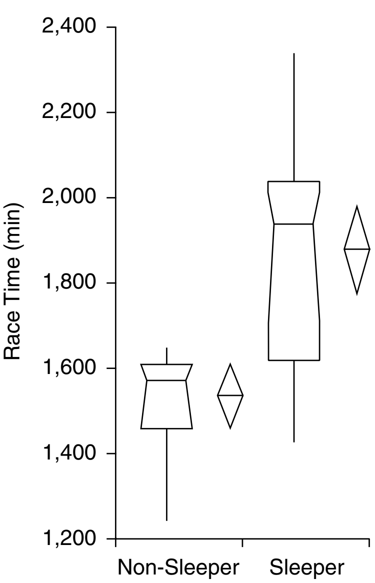

Fig. 1. The 23 non-sleepers in the finisher group completed the race within 1,567 (1,453-1,606) min, highly significantly faster than the 31 sleepers with 1,934 (1,615-2,033) min ($P = 0.0003$).

Table 4. Association of anthropometry with race time in finishers (n = 54)

	Association with race time
Body height	0.04
Body mass	0.17
Body mass index	0.16
Percent body fat	0.43, $P = 0.0017$
Skeletal muscle mass	-0.25

P-value is inserted in case of a significant association.

Table 5. Association of training variables with race time in finishers (n = 54)

	Association with race time
Years as active cyclist	0.02
Kilometres covered in the year before race	-0.25
Number of training units in cycling per week	-0.05
Minimal cycling distance per training unit	-0.30
Maximal cycling distance per training unit	-0.23
Mean cycling distance per training unit	-0.36, $P = 0.0201$
Mean duration per training unit	-0.31, $P = 0.0449$
Mean speed per training unit	-0.07
Mean weekly distance in cycling	-0.12
Mean weekly duration of training	-0.18
Number of finished 'Swiss Cycling Marathons'	-0.14

P-value is inserted in case of a significant association.

Table 6. Association of equipment, support and sleep with race time

	Association with race time
Weight of the race bike	0.38
Racing with support crew	-0.17
Racing following GPS	-0.19
Racing with replacement bike	-0.20
Racing using own nutrition	-0.16
Sleep during the race	0.50, $P = 0.0040$

Time invested in sleeping was related to overall race time. *P*-value is inserted in case of a significant association.

Table 7. Multivariate analysis with race time as the dependent variable (n = 54)

	ß	SE	*P*-value
Percent body fat	21.29	8.57	0.026
Mean cycling distance per training unit	2.61	2.78	0.363
Mean duration per training unit	-3.12	0.93	0.005
Sleep during the race	0.84	0.44	0.080

Associations between race time as the dependent variable and athletes' characteristics using multiple linear regression; ß = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (r^2) of the model was 73%.

with race time after bivariate analysis were entered into the multiple linear regression model (see Table 7), percent body fat (see Fig. 3) and the mean duration per training unit (see Fig. 4) remained predictor variables for overall race time. Percent body fat showed no association with the cycling volume in the year before the race, with weekly cycling kilometres, weekly cycling hours and cycling speed in training ($P > 0$ .05).

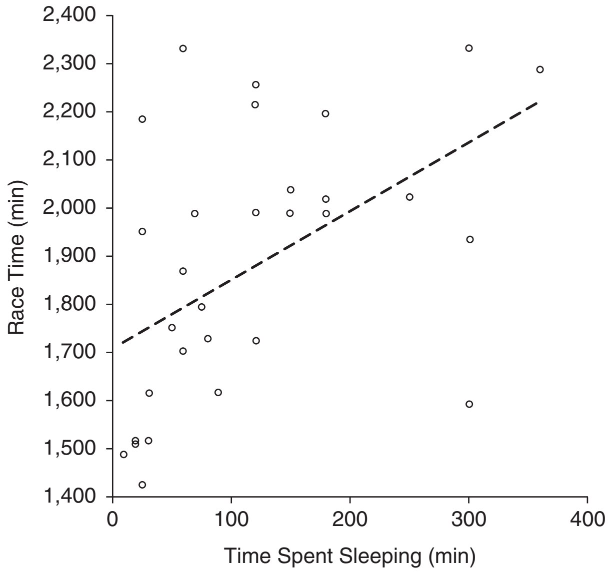

Fig. 2. Time spent in sleeping during the race was significantly and positively related to overall race time (n = 31) (r = 0.50, P = 0.0040).

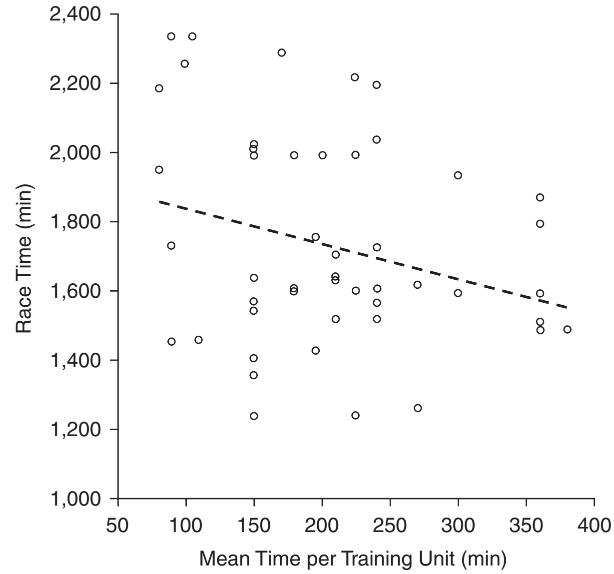

Fig. 4. The mean duration per training unit was significantly and negatively related to overall race time (n = 54) (r = -0.31, P = 0.0449).

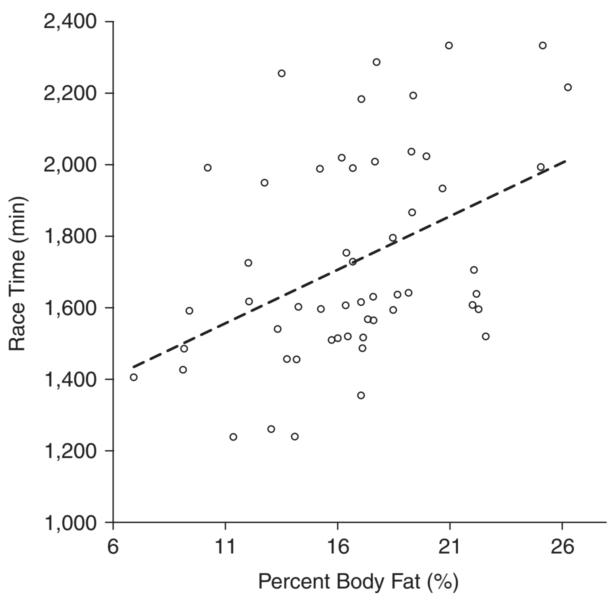

Fig. 3. Percent body fat was significantly and positively related to overall race time (n = 54) (r = 0.43, P = 0.0017).

Discussion

The aim of the study was to investigate potential associations between characteristics of anthropometry, training and race support with overall race time in order to find predictor variables for race performance in a cycling ultra-marathon such as the 'Swiss Cycling Marathon'. We hypothesized that variables of both anthropometry and training would be related to total race time. We expected also to find a relationship between equipment and support during the race with race time. Regarding recent findings in a case report in the 'RAAM' (30), we speculated that athletes with rests might be faster than athletes without rests.

After bivariate analysis, variables of anthropometry such as percent body fat, variables of training such as distance and duration per training unit and time invested in sleeping during the race were associated with overall race time. However, we found no association with variables of support during the race. When all significant variables entered the multiple linear regression model, percent body fat and the mean duration per training unit remained the single predictor variable for total race time. In addition, those finishers with naps were highly significantly slower compared to those finishers riding through the course without a break.

The finding that training volume such as distance and duration per training unit were related to race performance in ultra-endurance cyclists is in accordance with previous literature (19). However, literature regarding the association between training and race performance in cyclists is rather scarce (10, 31). In cyclists, long-term training programmes seemed to be of importance for cycling performance (31). Also, in long-distance triathletes, training distances seemed to be more important than training paces in the preparation for an Ironman triathlon (7, 27). In a previous study on ultra-endurance cyclists, it was supposed that cycling speed in training would be related to race time in an ultra-cycling marathon rather than training volume (19). However, also in this larger sample of ultra-cyclists, training volume was not related to race time. In addition, cycling speed in training showed no association with race performance.

We also investigated a potential association between anthropometric factors and race time since, in studies of ultra-endurance athletes such as ultra-runners and ultra-cyclists, anthropometric variables such as body mass (15), body mass index (9) and body fat (19) were related to race performance. In ultra-cyclists, body fat showed an association with performance (19). After both the bivariate and the multivariate analyses, percent body fat was related to race time in these subjects. One might also assume that other anthropometric variables such as body mass (33, 34) might also be associated with race time in ultra-endurance cyclists as has been described in previous studies on cyclists (5, 12, 13, 33, 34). However, body mass was not related to overall race time in these ultra-endurance cyclists after bivariate analysis.

An interesting finding was that in both finishers and non-finishers, a part of the athletes took a break for sleep. Schumacher *et al.* (30) considered regular recovery and sleep as an alternative strategy for a successful finish in an ultra-endurance cycling race such as the 'RAAM'. In the finishers, 31 cyclists (57%) went to sleep; in the non-finishers, three cyclists (23%) took a longer break for sleep. The sleep duration was no different between finishers and non-finishers. However, the non-sleepers were highly significantly faster compared to the sleepers. Interestingly, finishers could finish the race despite the break, although the length of the sleep break was significantly and positively related to race time. Cyclists in 'Paris-Brest-Paris' can choose whether they want to finish the 1,200 km within 90 h, 84 h or 80 h. One can imagine that it is nearly impossible to stay awake for 80 h without a break for rejuvenation in order to complete a cycling distance of 1,200 km. Endurance performance leads to sleep disruption depending upon the length of the performance (3). Presumably these athletes had already tried to prepare during the qualifier for 'Paris-Brest-Paris' by taking short breaks for sleep. In a recent study in ultra-triathletes, it was concluded that ultra-endurance athletes developed their own racing strategy for an ultra-endurance race based upon their previous experience (8). Meney *et al.* (24) reported a considerable inter-individual variation in response to sleep loss. It is possible for a sailor to cross the Atlantic with 3 h of sleep per day (6) and sleep deprivation of 30 to 72 h does not affect cardiovascular and respiratory responses to exercise of varying intensity, or the aerobic and anaerobic performance capability of individuals (35, 36). It seems that the physical performance is less impaired than the psychological performance after sleep deprivation (22, 36). However, intense physical exercise is considerably impaired after sleep deprivation compared to endurance exercise of moderate intensity (4, 23, 36). An ultra-endurance cycling race is completed at a low to moderate intensity (16) and sleep deprivation might therefore not exhibit too negative side effects especially when the race is completed within 24 to 36 h.

In a longer race such as the 'RAAM', however, a loss of concentration due to sleep deprivation may have fatal consequences. In the 2005 edition of the 'RAAM', the ultra-endurance cyclist Bob Breedlove hit a truck after four days and 1,100 miles into the race and died (http://www.ultracycling.com/about/hof_breedlove.html). While it is possible to complete 600 km without sleep, it is impossible to complete the 'RAAM' without sleep (11, 16, 30). However, sleeping strategies in the 'RAAM' may be different. The ultra-endurance cyclist Michael Nehls (www.michael-nehls.de) finished the 'RAAM' upon his first participation on 7th position after ~11 days. He made a total of ~91 h of breaks, ~70 h more than the other competitors. During the race, however, no competitor was able to pass him.

The comparison of variables between finishers and non-finishers might give more information about whether training, anthropometry or support during the race were associated with race performance, since 13 non-finishers were not able to complete the 600 km cycling race. When regarding pre-race experience, no non-finisher had completed a race of this length, whereas 21 finishers (39%) had already completed such a race. However, the number of completed races for finishers was not associated with race time. This finding supports recent findings of the importance of previous experience in ultra-endurance for a successful finish of an ultra-endurance race (8).

This study is limited that we collected data in two different years in order to increase the sample size. Despite similar temperatures in both years, the environment conditions such as wind direction and intensity and relative humidity could have affected performance. However, finish times were not different between finishers in the two years. Body mass of the athlete was measured without equipment and weight of the bike was determined without additional equipment such as full drinking bottles. So we must be aware that athletes had carried around more weight during the race. However, athletes were able to pass the baggage to the crew or they could leave their baggage behind at a check point to be transferred to the finish. So the average weight of a rider including bike and equipment could considerably 2 changes during the race. Unfortunately, we were not able to record food and fluid intake since nutrition during an ultra-endurance performance is crucial for a successful race outcome (28, 29).

To summarize, for a successful finish in a cycling ultra-marathon such as the 'Swiss Cycling Marathon', percent body fat and training volume were related to race time whereas equipment and support during the race showed no association. The non-sleepers in the finisher group completed the race highly significantly faster than the sleepers. In a race of ~24 h of duration, sleep deprivation seems not to impair performance. Regarding the fact that 20% of the participants dropped out and 57% of the finishers and 23% of the non-finishers had to take a longer rest with sleep, other factors such as motivation might also influence race outcome. In future studies on ultra-endurance cyclists, the aspect of motivation should be investigated. Future studies should also investigate whether short 'power naps' or longer breaks for sleeping might be of benefit for a faster race time in the 'RAAM'.

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