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Changes in Skinfold Thicknesses and Body Fat in Ultra-endurance Cyclists

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- A** Concept / Design
- B** Acquisition of Data
- C** Data Analysis / Interpretation
- D** Manuscript Preparation
- E** Critical Revision of the Manuscript
- F** Funds Collection
- G** Approval of the Article

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Conclusion: Cycling 600 km at ~23 km/h led to a decrease in fat mass and in all skinfold thicknesses. The largest decrease in skinfold thickness was recorded for pectoral, abdominal, and thigh site. The decrease in abdominal skinfold thickness was negatively related to cycling speed. The body seems to reduce adipose subcutaneous fat during an ultra-endurance performance at the site of the thickest skinfold.

Key Words: Endurance; Fat Mass; Muscle Mass; Anthropometry; Body Fat; Training

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INTRODUCTION

In recent years, several studies reported that an ultra-endurance performance leads to a decrease in solid mass such as fat mass^[1-5] or skeletal muscle mass^[6-10]. The type of the exercise seems to affect whether muscle mass or fat mass will be decreased. Eccentric endurance performance such as running seems to lead to a decrease in both muscle mass and fat mass^[3,4,7,9,10] whereas a concentric endurance performance such as cycling seems to reduce fat mass^[11].

For cyclists, a reduction in fat mass has been reported where skeletal muscle mass was spared^[11]. However, the specific sites of a decrease in body fat

have not been recorded^[11]. During cycling, the lipolysis of adipose subcutaneous tissue was different between different sites on the exercising body^[12]. Boschmann et al^[12] showed in a laboratory trial differences between women and men during a standardized bicycle exercise on metabolism and blood flow in abdominal and femoral subcutaneous adipose tissue and skeletal muscle. Lipolysis was greater in muscle tissue than in femoral subcutaneous adipose tissue and greater in femoral subcutaneous adipose tissue than in abdominal subcutaneous adipose tissue. In muscle tissue, the increase in lipolysis was greater for women compared to men. The authors concluded that (i) lipids stored in muscle tissue were used rather

than lipids stored in adipose tissue for fueling the energy metabolism of muscle during exercise and (ii) lipid mobilization during exercise was much greater in women than in men. The most important finding with practical application was, however, that lipolysis of subcutaneous adipose tissue was greater in femoral than in abdominal adipose subcutaneous tissue.

The aim of the present study was to investigate the changes in skinfold thicknesses in ultra-endurance cyclists in a single stage ultra-cycling race. We hypothesized, firstly, that fat mass would decrease and, secondly, the skinfold thickness at the thigh site would decrease to a larger extent than the skinfold thickness at the abdominal site.

METHODS AND SUBJECTS

Subjects:

The 'Swiss Cycling Marathon' (www.radmarathon.org) takes place every year and offers a 600-km loop in order to qualify for the ultra-cycling marathon 'Paris-Brest-Paris' (www.paris-brest-paris.org). Since only a small number of athletes participate in ultra-endurance races [2-11], we collected data in three subsequent years from 2008 until 2010 in order to increase the sample size. Athletes competing in all three years were included upon their first participation. All participants provided consent. The study was approved by the Ethical Committee of Canton St. Gallen, Switzerland. A total of 119 recreational athletes with (mean± standard deviation) 43.3±7.7 years of age, 1.80±0.06 m

of body height, 78.5±8.2 kg of body mass and a body mass index of 23.9±2.1 kg/m² completed the 600 km within the time limit of 40 hours.

The Race:

The 'Swiss Cycling Marathon' takes place at the end of June/beginning of July. For the 600 km with a total altitude of ~4,700 m (Fig. 1), the athletes started outside of Berne, Switzerland, and cycled to the southern border of Germany. Then, they cycled along 'Lake Constance' towards the Alps of Eastern Switzerland and turned then back to Berne. In total, they had to pass 12 check points (Table 1).

Weather conditions were comparable in all three years. Daily highs varied between 22° Celsius and 25° Celsius, night lows were between 9° Celsius and 11° Celsius.

Measurements and Calculations:

Before the start of the race and upon arrival at the finish line, anthropometric characteristics such as body mass, circumferences of limbs and the thickness of skinfolds at pectoral, axillar, triceps, subscapular, abdomen, suprailiacal, front thigh and medial calf site were measured. With these anthropometric measurements, the sum of skinfold thicknesses, percent body fat, fat mass, and skeletal muscle mass were estimated using anthropometric equations.

Body mass was measured after voiding, using a commercial scale (Beurer BF 15, Beurer GmbH, Ulm, Germany) to the nearest 0.1 kg. Body height was determined using a stadiometer (TANITA HR 001, Tanita Europe B.V., Amsterdam, Netherlands) to the nearest 0.01 m. The circumferences of upper arm, thigh

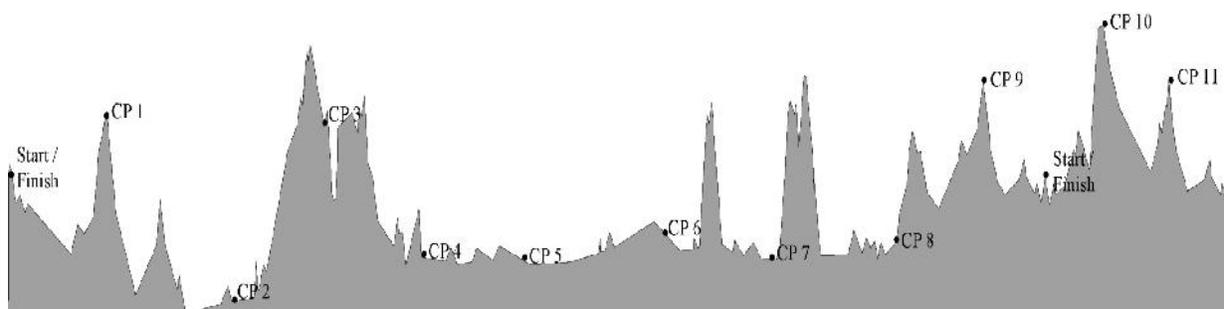


Fig. 1: Profile of the course

Table 1: Checkpoints, distance, altitude and increase and decrease along the track

Checkpoint	Distance (km)	Altitude (m above sea level)	Increase (m)	Decrease (m)
Start/Finish Ittigen	0	591	0	0
CP 1 Langenbruck	56.7	706	382	254
CP 2 Koblenz	131.6	319	704	979
CP 3 Ewattingen	184.3	714	1,423	1,308
CP 4 Ramsen	242.1	418	1,923	2,102
CP 5 Frasnacht	301.3	409	2,020	2,207
CP 6 Sargans	382.3	485	2,180	2,304
CP 7 Pfäffikon	445.1	414	2,616	2,799
CP 8 Emmenbrücke	518.1	443	3,359	3,506
CP 9 Affoltern	569.1	801	3,922	3,716
Start/Finish Ittigen	605.2	591	4,089	4,089
CP 11 Jassbach	639.1	920	4,610	4,280
CP 9 Affoltern	677.3	801	4,834	4,624
Start/Finish Ittigen	713.4	591	4,993	4,993

and calf were measured using a non-elastic tape measure (KaWe CE, Kirchner und Welhelm, Germany) to the nearest 0.1 cm. The circumference of the upper arm was measured at mid-upper arm, the circumference of the thigh was taken at mid-thigh and the circumference of the calf was measured at mid-calf. Skinfold data were obtained using a skinfold caliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) and recorded to the nearest 0.2 mm. The skinfold calliper measures with a pressure of 0.1 Mpa ± 5% over the whole measuring range. One trained investigator took all the measurements. All skinfold thicknesses were determined on the right side of the body in all the athletes. The skinfold measurements were taken three times and the mean was then used for the analyses. The skinfold measurements were standardized to ensure reliability and readings were performed 4s after applying the calliper, according to Becque et al. [13]. Intra and inter-rater agreement was assessed in data from 27 male runners prior to an ultra-marathon, based on measurements taken by two experienced primary care physicians [14].

Percent body fat was estimated using the anthropometric formula according to Ball et al. [15] with percent body fat = 0.465 + 0.180 × (Σ7SF) – 0.0002406 × (Σ7SF)² + 0.0661 × (age) where Σ7SF = sum of skinfold thickness of pectoralis, axillar, triceps, subscapular, abdomen, suprailiac and thigh. This formula was evaluated using 160 men aged 18 to 62

years old and cross-validated with DXA (dual energy X-ray absorptiometry). The mean differences between DXA percent body fat and calculated percent body fat ranged from 3.0% to 3.2%. Significant (*P*<0.01) and high (*r*>0.90) correlations existed between the anthropometric prediction equations and DXA. Fat mass was estimated using the anthropometric method of Stewart and Hannan [16] with fat mass (g) = 331.5 × (abdominal) + 356.2 × (thigh) + 111.9 m – 9,108 where abdominal is the thickness of abdominal skinfold in mm, thigh is the thickness of thigh skinfold in mm and m is body mass in kg. Skeletal muscle mass was estimated using the formula following Lee et al. [17] with skeletal muscle mass = Ht × (0.00744 × CAG² + 0.00088 × CTG² + 0.00441 × CCG²) + 2.4 × sex – 0.048 × age + race + 7.8 where Ht = height, CAG = skinfold-corrected upper arm girth, CTG = skinfold-corrected thigh girth, CCG = skinfold-corrected calf girth, sex = 1 for male, race = 0 for white. This anthropometric method was evaluated using 189 non-obese subjects and cross-validated using MRI (magnetic resonance imaging) evaluation. Changes (Δ) in total body water were estimated using the equation Δ total body water = Δ body mass – (Δ skeletal muscle mass + Δ fat mass) + endogenously produced water where endogenously produced water = water produced by oxidation of fuel + glycogen-complexed water following Weschler [18]. Body mass index was calculated using body weight in kilograms

divided by the square of body height in meters (kg/m^2). The athletes were categorised following the international classification of adults: underweight, overweight and obese according to body mass index of the World Health Organization (WHO) (<http://apps.who.int/bmi/index>).

Statistical analysis:

Statistical analyses were performed using IBM SPSS Statistics (Version 19, IBM SPSS, Chicago, IL, USA). Data are presented as mean \pm standard deviation (SD). Pre- and post-race results were compared using paired *t*-test. Pearson correlation was used to investigate a potential association between variables. Significance was accepted at $P < 0.05$ for all statistical tests.

RESULTS

A total of 119 subjects finished the race successfully within the time limit. The subjects had a pre-race body mass index of $23.9 \pm 2.1 \text{ kg}/\text{m}^2$. No subject was underweight (BMI 16.0-18.5 kg/m^2), 84 subjects (70.6%) were of normal weight (BMI 18.5-25.0 kg/m^2), 34 subjects (28.6%) were overweight (BMI 25.0-30.0 kg/m^2) and one subject (0.8%) was obese (BMI $> 30.0 \text{ kg}/\text{m}^2$).

The subjects were riding at a mean speed of $23.5 \pm 4.0 \text{ km}/\text{h}$ and finished the race within $1,580 \pm 296 \text{ min}$. Body mass decreased by $1.5 \pm 1.2 \text{ kg}$ ($P < 0.001$), estimated fat mass decreased by $1.5 \pm 1.1 \text{ kg}$ ($P < 0.001$) while both estimated skeletal muscle mass ($P > 0.05$) and estimated total body water ($P > 0.05$) remained unchanged (Table 2). The decrease in body mass correlated to the decrease in estimated fat mass ($r = 0.20$, $P = 0.03$) (Fig. 2). The decrease in estimated fat mass was not related to cycling speed during the race ($r = 0.08$, $P = 0.4$).

All skinfold thicknesses decreased where the skinfold thicknesses at pectoral, abdominal, and thigh site showed the largest percent decreases (Table 2). The decrease in abdominal skinfold was significantly and negatively related to cycling speed during the race ($r = -0.36$, $P < 0.001$) (Fig. 3). However, the decrease in both pectoral ($r = 0.03$, $P = 0.7$) and thigh skinfold ($r = -0.04$, $P = 0.7$) was not associated with cycling speed.

DISCUSSION

Changes in body composition:

All skinfold thicknesses decreased during the race and therefore both estimated body fat and estimated fat mass decreased whereas estimated skeletal muscle

Table 2: Changes of solid masses and skinfold thicknesses (n=119)

Variable	Pre-race	Post-race	Change absolute	Change in percent	P Value
Body mass (kg)	78.5 (8.2)	77.1 (7.7)	- 1.5 (1.2)	- 1.7 (1.5)	<0.001
Skinfold pectoral (mm)	7.3 (3.3)	6.1 (2.9)	- 1.2 (1.7)	- 14.7 (14.4)	<0.001
Skinfold axillar (mm)	8.7 (3.4)	7.9 (3.1)	- 0.8 (1.1)	- 8.6 (11.0)	<0.001
Skinfold triceps (mm)	7.7 (3.2)	7.0 (3.1)	- 0.6 (0.8)	- 8.5 (9.5)	<0.001
Skinfold subscapular (mm)	10.6 (4.5)	9.9 (4.4)	- 0.7 (1.2)	- 6.9 (7.6)	<0.001
Skinfold abdominal (mm)	17.1 (8.6)	14.7 (7.8)	- 2.4 (2.1)	- 14.9 (11.4)	<0.001
Skinfold suprailiacal (mm)	15.6 (6.7)	14.3 (6.8)	- 1.3 (2.1)	- 9.7 (13.7)	<0.001
Skinfold front thigh (mm)	12.5 (5.8)	11.1 (4.5)	- 1.4 (1.8)	- 10.2 (9.5)	<0.001
Skinfold medial calf (mm)	6.0 (2.9)	5.6 (2.8)	- 0.4 (0.8)	- 6.4 (15.6)	<0.001
Sum of skinfolds (mm)	85.5 (31.3)	76.7 (29.1)	- 8.8 (5.6)	- 10.7 (5.6)	<0.001
Percent body fat (%)	15.9 (4.2)	14.7 (4.1)	- 1.2 (0.7)	- 7.6 (4.1)	<0.001
Fat mass (kg)	9.8 (4.4)	8.3 (4.0)	- 1.5 (1.1)	- 16.0 (10.4)	<0.001
Skeletal muscle mass (kg)	40.0 (3.7)	40.3 (3.6)	0.3 (0.5)	0.8 (1.4)	
Total body water (L)	28.6 (4.3)	28.4 (3.8)	- 0.2 (1.5)	- 0.4 (6.1)	

Results are presented as mean (Standard Deviation)

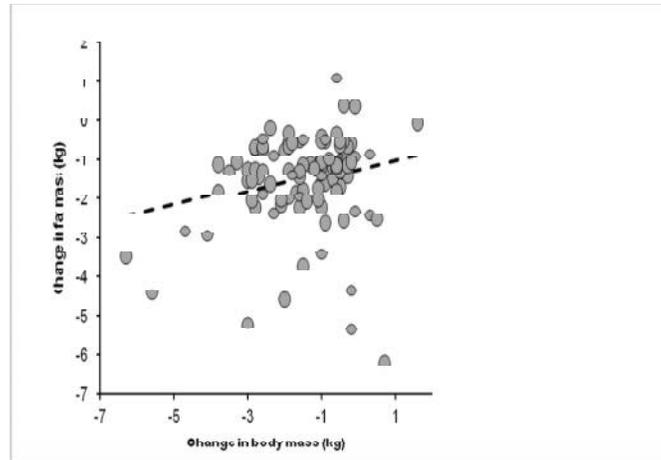


Fig. 2: The change in body mass was associated with the change in fat mass ($n=119$) ($r= 0.20$, $P= 0.03$)

mass remained unchanged. Former findings supported the assumption that an ultra-endurance performance lead to a decrease in body mass, mainly due to a decrease in fat mass [1,2] and also in the present study a correlation between these two variables was found. As speed during the race was low, presumably no skeletal muscle damage occurred and the loss in body mass was mainly attributed to the degradation of subcutaneous adipose tissue as an energy source.

Generally, skeletal muscle mass in ultra-cycling races remained unchanged [11,19,20]. On the other hand, ultra-endurance performances such as running, with its

eccentric component, lead to a damage in skeletal muscle cells [21] and therefore to a decrease in skeletal muscle mass [9,10]. During such an ultra-endurance race, the athletes also rest several times [22], implying that muscular glycogen may have had the possibility to be restored [23]. In contrast, a study investigating ultra-endurance mountain bike cyclists showed a decrease in skeletal muscle mass, possibly attributed to the shocks an athlete is exposed to at mountain bike races including downhill parts leading to muscle damage and proteolysis [8]. In addition, intramyocellular lipids form an important substrate source in prolonged exercise and

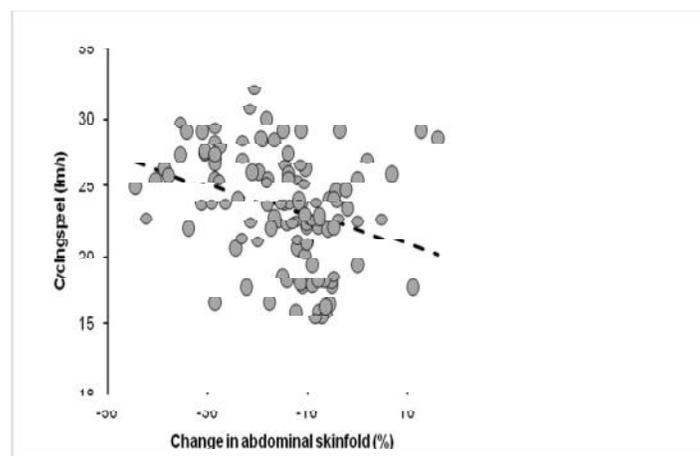


Fig. 3: The change in abdominal skinfold thickness was significantly and negatively related to cycling speed ($n=119$) ($r = - 0.31$, $P < 0.001$)

might lead to a decrease in skeletal muscle mass as well [24,25].

Changes in specific skinfold sites:

Our second hypothesis was that the skinfold thickness at the thigh site would decrease to a larger extent than the skinfold thickness at the abdominal site. We found, however, that the skinfold at the abdominal site decreased to a higher extent (-14.9±11.4%) compared to the front thigh site (-10.2±9.5%). The skinfold thickness at the pectoral, abdominal and thigh site showed the largest percent decreases. The considerable decrease at the pectoral site was presumably due to the upper body work holding the bicycle handlebar. However, in a study in a non-stop ultra-triathlon [5], the skinfold thicknesses decreased predominantly on the upper body where the pectoral skinfold was spared. The combination of swimming, running and cycling in a triathlon might explain these disparate findings in reducing adipose subcutaneous fat tissue during endurance performance. Interestingly, in that study, no decrease in thigh skinfold thickness was found [5]. Low skinfolds at the upper body seem to be important for ultra-endurance performances in male athletes. In male Ironman triathletes the sum of upper body skinfolds was related to overall race time [26]. In addition, the sum of upper body skinfolds was also associated with cycling speed during the race. For female athletes, however, none of the skinfold thicknesses showed an association with total race time.

Previous findings from Boschmann et al. [12] support our observation of a decrease of femoral adipose tissue at the thigh. Their subjects were cycling, using their leg muscles and showed an increase of lipolysis of femoral adipose tissue. However, in the present ultra-endurance cyclists, the percent decrease in the abdominal skinfold thickness was higher compared to the decrease in the thigh skinfold thickness. In addition, the decrease in the abdominal skinfold thickness was related to cycling speed. These disparate findings might be explained by the present subjects where 34 subjects (28.6%) were categorised overweight and one subjects (0.8%) was categorised obese. The abdominal skinfold thickness was the thickest of all skinfolds which might be explained by its function as a place of major fat storage [27]. Most probably the body reduces body fat at the site

of the thickest skinfolds. The same finding has also been reported for male ultra-swimmers [28]. In male open-water ultra-swimmers, the thickest skinfolds were at suprailiacal (25.0±8.3 mm), abdominal (21.0±9.2 mm), and front thigh (14.2±6.0 mm) site. The largest decrease in skinfold thickness was found at abdominal (-8.4±9.6%) and suprailiacal (-7.5±19.4%) site. At the front thigh site, there was even an increase in skinfold thickness (+11.2±17.3%).

Limitations and implications for future research:

A limitation of this study was that we did not record energy and fluid intake. In addition, we did not record the time the athletes spent resting. A recovery phase with sleep may help replenish the depleted intramyocellular stores [23]. This might explain why skeletal muscle mass was not reduced after a race, but fat mass was. Krssak et al. [23] presumed a transfer of glycogen from the resting muscle (*i.e.* forearm) to recovering muscles (*i.e.* thigh and calf) after their subjects ran on a treadmill till exhaustion. Further, Kimber et al. [29] showed a high metabolic priority towards glycogen resynthesis and unchanged intramyocellular triglycerides during immediate post-exercise recovery. Future studies using nuclear magnetic resonance imaging of intramyocellular glycogen and lipids as well as dual-energy x-ray absorptiometry might show in more details how skeletal muscle mass and adipose subcutaneous tissue change during ultra-endurance performance [30-32]. In some subjects, skinfold thicknesses increased which might be due to fluid overload [33].

CONCLUSION

The present findings suggest for ultra-endurance cycling that (i) adipose subcutaneous tissue becomes reduced at both the upper and lower body and (ii) the thickest skinfolds showed the largest decrease. The decrease in abdominal skinfold thickness was negatively related to cycling speed. Overweight and obese athletes might profit from long-distance cycling in order to reduce their adipose subcutaneous tissue

primarily at the abdominal site. Future studies might compare the effects of cycling and running training in overweight and obese on skinfold thickness and body fat.

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Conflict of interests: None

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