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Research Article

SKIN-FOLD THICKNESS AND RACE PERFORMANCE IN MALE MOUNTAIN ULTRA-MARATHONERS

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ABSTRACT
Recent studies showed in high level runners both an association between selected skin-fold thicknesses at the lower limb and running performance and between thickness of skin-fold and training. We investigated the association of skin-fold thicknesses with total race time in 25 male mountain ultra-marathoners with 44.5 (7.0) years, 73.0 (7.8) kg body mass, 1.78 (0.07) m body height and a BMI of 22.9 (1.8) kg/m^2 in a 7-day mountain ultra-marathon over 350 km with 11,000 m of altitude. The relationship of skin-fold thickness and both intensity and volume during training with total race time as the dependent variable was investigated using multiple linear regression analysis. A significant association of the calf skin-fold with total race time was found ($r^2 = 0.19$, $p < 0.05$). No relationship between skin-fold thickness and both average running speed and volume in training could be demonstrated. We concluded that the calf skin-fold showed a small to moderate association with total race time, however, the thickness of calf skin-fold was not related to training parameters.

Key words: *anthropometry – percent body fat – ultra-endurance.*

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INTRODUCTION

In runners, different factors possibly affecting performance are described. Apart from physiological variables such as maximal oxygen uptake and lactate threshold, several different anthropometric variables, albeit depending upon the duration of running, showing a relationship with performance such as body mass (Bale, Bradbury and Colley, 1986; Hagan, Smith and Gettman, 1981; Knechtle, Duff, Welzel and Kohler, 2009), body height (Bale, Bradbury and Colley, 1986; Loftin et al., 2007; Maldonado, Mujika and Padilla, 2002), body mass index (BMI) (Hagan, Upton, Duncan and Gettman, 1987; Hoffman, 2008; Lucia et al., 2006), body fat (Hagan, Upton, Duncan and Gettman, 1987), total skin-fold thickness (Bale, Bradbury and Colley, 1986; Hagan, Smith and Gettman, 1981), skin-fold thickness of the lower limb (Arrese and Ostáriz, 2006; Bale, Bradbury and Colley, 1986; Legaz and Eston, 2005; Legaz Arrese, Gonzalez Badillo and Serrano Ostáriz, 2005), length of legs (Larsen, Christensen, Nolan and Søndergaard, 2004; Tanaka and Matsuura, 1982) and circumferences of limbs (Knechtle, Knechtle, Schulze and Kohler, 2007; Knechtle, Duff, Welzel and Kohler, 2009; Lucia et al., 2006; Tanaka and Matsuura, 1982).

These anthropometric factors appear to have different statistical weight depending on the running distance. Body height seems to be associated with performance in running 10,000 m (Bale, Bradbury and Colley, 1986) and marathons (Loftin et al., 2007). BMI is associated with marathon (Hagan, Upton, Duncan and Gettman, 1987) and ultra-marathon performances (Hoffman, 2008). In addition to BMI, body fat seems to have an effect on running time and is associated with marathon performance times (Hagan, Upton, Duncan and Gettman, 1987). In some studies, a relationship between skin-fold thicknesses and performance has been described. Lower skin-folds are positively associated with improved running times up to 10,000 m (Arrese and Ostáriz 2006; Bale, Bradbury and Colley, 1986; Legaz and Eston, 2005; Legaz Arrese, Gonzales Badillo and Serrano Ostáriz, 2005) and skin-fold thicknesses in the lower limbs are associated with running times over 1,500 m and 10,000 m (Arrese and Ostáriz, 2006; Bale, Bradbury and Colley, 1986) as well as the marathon distance (Bale, Rowell and Colley, 1985). The length of the upper leg has shown an association with running times over 800 m, 1,500 m and 5,000 m (Tanaka and Matsuura, 1982). Circumference of the thigh is also associated with running times over 800 m, 1,500 m and 5,000 m, whereas upper arm circumference has shown an association with 10,000 m running times (Tanaka and Matsuura, 1982) and in distances over more than 300 km (Knechtle, Knechtle, Schulze and Kohler, 2007; Knechtle, Duff, Welzel and Kohler, 2009).

There is very little scientific data on the influence of anthropometry on race performance in ultra-marathon running (Bale, Rowell and Colley, 1985; Hetland, Haarbo and Christiansen, 1998; Knechtle, Knechtle, Schulze and Kohler, 2007; Knechtle, Duff, Welzel and Kohler, 2009; Tokudome et al., 2004).Especially, there is no data about the association of anthropometry and performance in mountain ultra-marathoners. Ultra-running means distances longer than the classic marathon distance of 42,195 km. Ultra-marathoners seem to have a lower BMI compared to sedentary people (Tokudome et al., 2004) and have low amounts of fat at the abdomen and legs (Hetland, Haarbo and Christiansen, 1998). These low amounts of body fat are supposed to be the result of intense training in ultra-runners (Hetland, Haarbo and Christiansen, 1998) and this intense training may lead to an improved performance (Bale, Rowell and Colley, 1985). Probably a thinner upper body with low circumferences of the upper arm is also advantageous for runners in ultra-distances as has been shown in races of 300 km (Knechtle, Duff, Welzel and Kohler, 2009) and 1,200 km (Knechtle, Knechtle, Schulze and Kohler, 2007).

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Regarding the effect of body fat on running performance, the relationship between skin-fold thickness and performance has been intensely investigated in runners up to the marathon distance. Hagan, Smith and Gettman (1981) demonstrated that apart from other variables, the sum of 7 skin-folds is correlated with marathon performance time. Total skin-fold thickness, the type and frequency of training and the number of years running were the best predictors of running performance and success at the 10,000 m distance according to Bale, Bradbury and Colley (1986). In very recent studies, a relationship between the thicknesses of selected skin-folds and running performance has been demonstrated in high level runners (Arrese and Ostáriz 2006; Legaz and Eston, 2005). In these studies, elite runners of distances from 100 m to 10,000 m and the marathon distance had been investigated; high correlations were found between the front thigh and medial calf skin-fold with 10,000 m race times in male runners. It is supposed that the low skin-fold thicknesses of the lower limb are a result of intense training in running (Legaz and Eston, 2005).

The relationship between skin-fold thicknesses and race performance was investigated in all running distances from 100 m to 10,000 m and the marathon distance in male top level athletes; but not in mountain ultra-marathoners. We therefore intended to investigate possible correlations between skin-fold thicknesses and race performance in male ultra-endurance runners in a mountain ultra-marathon. Considering the fact that these ultra-endurance runners have to climb partly steep ascents, low skin-folds respectively low body fat would enhance performance. Furthermore, the training in running should show an association with skin-fold thickness. We hypothesized to find both an association between thickness of skin-folds and race performance and between thickness of skin-folds and training.

MATERIAL AND METHODS

Participants

All entrants of the 'Swiss Jura Marathon' 2008 were contacted by a separate newsletter from the organiser at the time of inscription to the race and were asked to participate in our investigation. The field of athletes was limited to 100 selected ultra-runners. Thirty-four male Caucasian ultra-runners were interested in our study. Subjects were informed of the experimental risks and gave informed consent prior to the investigation. The investigation was approved by the Institutional Review Board for use of Human subjects. Twenty-five out of our 34 subjects completed the race. Table 1 summarizes anthropometric variables of finishers and non-finishers, table 2 the training variables including pre race experience. Nine athletes dropped out between Stage 2 and 5 (on average after 3 Stages) due to overuse injuries of the lower limbs. The 18th edition of the 'Swiss Jura Marathon' took place from 6th July to 12th July 2008 as the longest mountain ultra-marathon in Europe. In this multi-day race, runners have to cover a total distance of 350 km with about 11,000 m of altitude in the 'Jura Mountains' (Switzerland) from Geneva to Basel (table 3) within 7 days. The race director organized accommodation and nutrition during the race.

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Table 1. *Comparison of anthropometric variables of finishers and non-finishers. Results are presented as mean (SD). No differences were found between finishers and non-finishers.*

Variables	**Finishers (n=25)**	**Non-Finishers (n=9)**
Age (y)	44.5 (7.0)	46.1 (7.8)
Body mass (kg)	73.0 (7.8)	71.3 (8.9)
Body height (m)	1.78 (0.07)	1.77 (0.04)
BMI (kg/m^2)	22.9 (1.8)	22.7 (2.6)
Skin-fold pectoralis (mm)	4.0 (1.7)	5.5 (4.4)
Skin-fold midaxillary (mm)	6.9 (2.5)	8.1 (4.7)
Skin-fold triceps (mm)	5.2 (2.3)	6.7 (2.7)
Skin-fold subscapular (mm)	8.6 (3.8)	10.1 (6.5)
Skin-fold abdominal (mm)	13.5 (5.7)	13.6 (8.6)
Skin-fold suprailiac (mm)	12.8 (6.0)	15.5 (7.2)
Skin-fold thigh (mm)	8.2 (4.6)	12.7 (10.1)
Skin-fold calf (mm)	3.8 (1.2)	4.7 (2.7)
Sum of 7 skin-folds (mm)	59.2 (20.8)	72.2 (38.3)
Percent body fat (%)	13.1 (3.2)	14.9 (5.0)

Table 2. *Comparison of training variables and previous race experience of finishers and non-finishers.*

Variables	**Finishers (n=25)**	**Non-Finishers (n=9)**
Years as active runner	11.2 (6.4)	12.6 (7.1)
Average weekly training volume in running (km)	79.5 (28.1)	71.1 (36.9)
Average weekly training volume in running (h)	8.1 (2.8)	7.7 (3.3)
Average speed in running during training (km/h)	10.6 (1.7) *	11.0 (0.8)
Personal best time in a marathon (min)	195 (26)	195 (24)
Years between personal best marathon time and race	4.7 (3.4)	4.0 (4.0)

Results are presented as mean (SD). Non-finishers were running significantly faster during training compared to finishers. (= $p < 0.05$).*

Table 3. *The 7 stages of the Swiss Jura Marathon including daily distance, altitude and general weather conditions during the race.*

Stage	**Distance (km)**	**Ascent (m)**	**Descent (m)**	**Temperature at the start (° Celsius)**	**Temperature at the finish (° Celsius)**	**General weather conditions**
1	47	1,410	750	12	14	Rain
2	45	1,290	1,320	10	12	Clouds
3	56	1,650	1,920	8	12	Clouds
4	47	2,020	1,760	8	20	Sun
5	53	1,520	2,090	14	26	Sun
6	50	1,780	1,720	18	27	Sun
7	52	1,490	1,700	14	22	Clouds

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Measurements and calculations

By the time of entering the race with the inscription, subjects kept a comprehensive training diary recording their training units in running with distance (km) and duration (h) until the start of the race. In addition, every athlete indicated his number of finished marathons (flat course) as well as his personal best time in marathon running. Before the start of the race body mass, body height, BMI, skin-folds at 8 sites, percent body fat and the sum of 8 skin-folds were determined using the anthropometric method. 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. Skin-fold thicknesses of pectoralis, midaxillary (vertical), triceps, subscapular, abdominal (vertical), suprailiac (at anterior axillary), thigh and calf were measured using a skin-fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) to the nearest 0.2 mm at the right side of the body. One trained investigator took all measurements as inter-tester variability is a major source of error in skin-fold measurements. Intra-tester reliability check was conducted on 27 male runners prior to testing. No significant difference between the 2 trials for the sum of 7 skin-folds was observed ($p > 0.05$). The intra-class correlation was high at $r = 0.95$. The same investigator was also compared to another trained investigator to determine objectivity. No significant difference existed between testers ($p > 0.05$). The measurements were taken once through entire 8 skin-folds and then repeated 3 times by the same investigator; the mean of the 3 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, Katch and Moffat (1986), readings were performed 4 s after applying the calliper. Percent body fat was calculated using the anthropometric formula following Ball, Altena and Swan (2004): Percent body fat = $0.465 + 0.180(\Sigma 7SF) - 0.0002406(\Sigma 7SF)^2 + 0.0661(age)$, where $\Sigma 7SF$ = sum of the 7 skin-fold thickness of chest, midaxillary, triceps, sub scapular, abdomen, suprailiac and thigh. This formula was evaluated with 160 men aged 18 to 62 years 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.

Statistical analysis

Results are presented as mean (SD). Athletes were categorized into 2 groups (finisher and non-finisher). Anthropometric and training variables were compared between groups by Kruskal-Wallis equality-of-populations rank test. In a first step, the relationship of the 8 measured skin-fold thicknesses with total race time was investigated with multiple linear regression analysis. In a second step, the skin-fold thicknesses were related to the average running speed and average weekly running volume during training. The coefficient of variation (CV % = 100 x SD/mean) of total race time was calculated. For all statistical tests significance was set at the 0.05 level.

RESULTS

A total of 83 male runners entered the race, 55 (66 %) athletes finished. From our panel of 34 subjects, 25 runners (71 %) finished within 44.2 (4.3) h and 26 (16) min respectively 2,677 (262) min (CV = 9.7 %). All 9 non-finishers dropped out between Stage 2 and Stage 5 due to overuse injures of the lower limbs. Table 1 shows the measured and calculated anthropometric variables of the athletes; table 2 indicates their training volume and the previous race experience. During training, finishers were slower running than non-finishers. The skin-fold of calf was related to total race time (figure 1) but not the thigh skin-fold (figure 2). Thickness of calf skin-fold was neither related to average weekly training volume in running kilometres (figure 3) nor to average running speed during training (figure 4).

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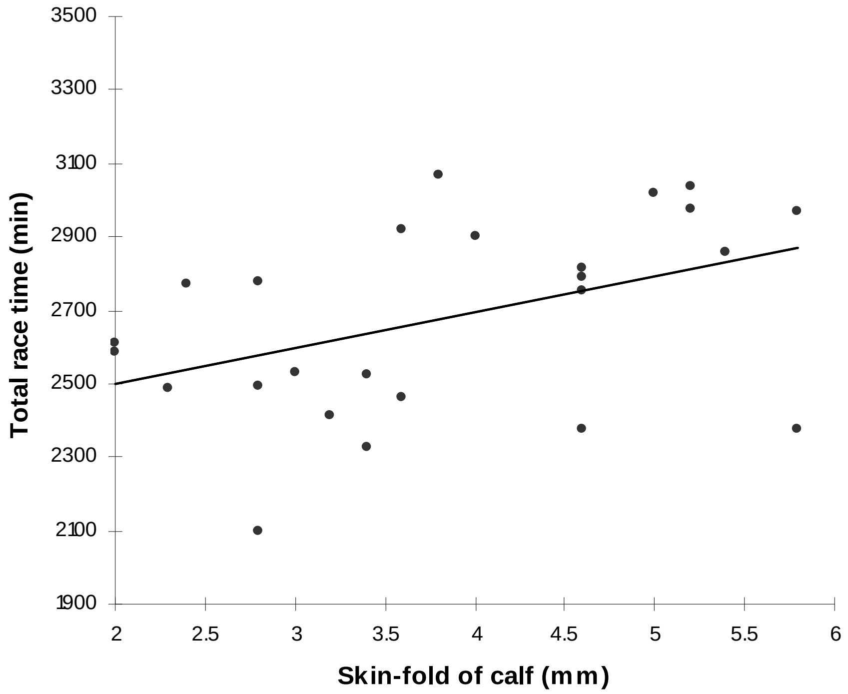

Figure 1. *Skin-fold of calf was related to total race time in the 25 finishers (r^2=0.19, $p<0.05$).*

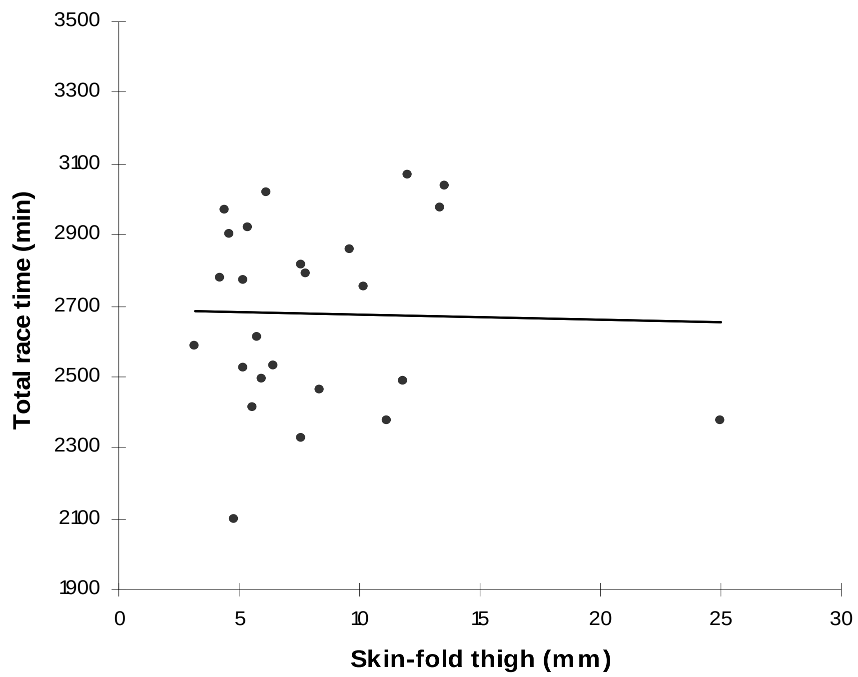

Figure 2. *Thigh skin-fold showed no association with total race time (r^2=0.001, $p>0.05$)*

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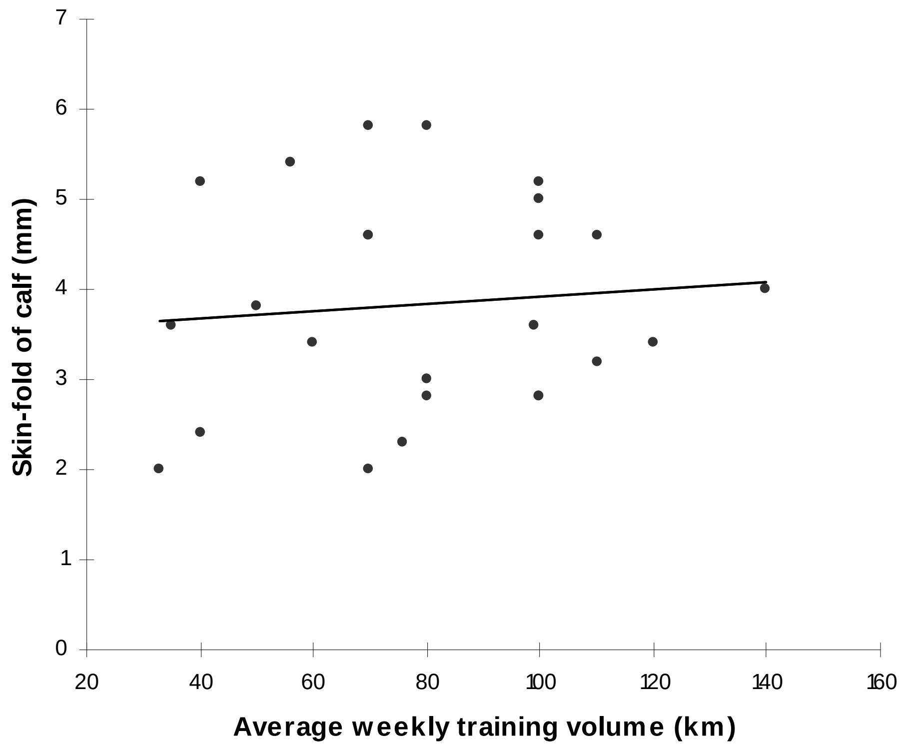

Figure 3. *The skin-fold of calf was not related to average weekly training volume (r^2=0.009; p>0.05).*

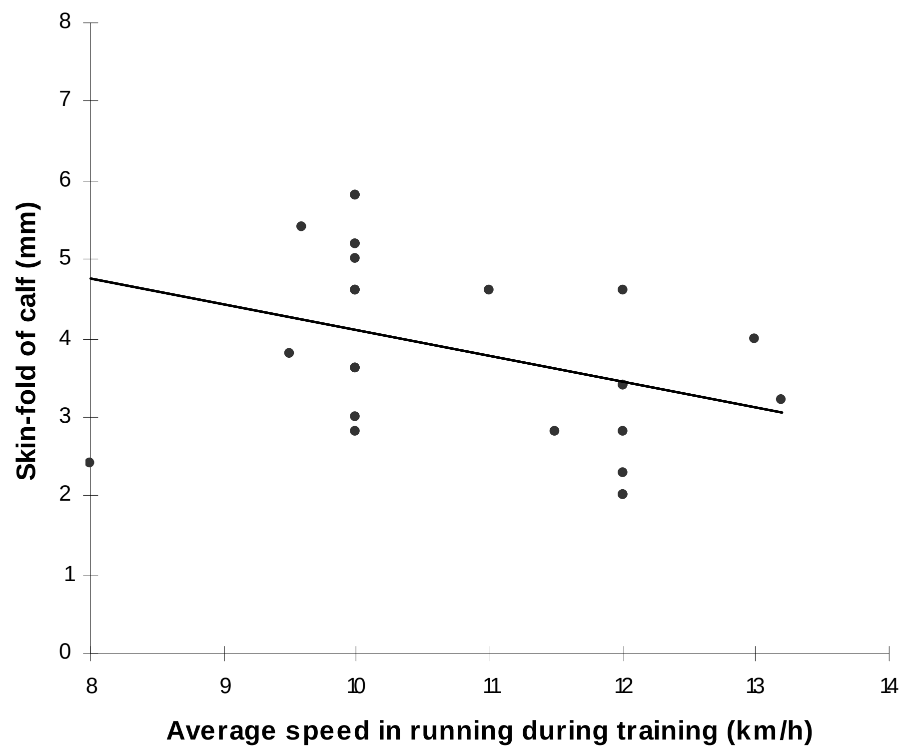

Figure 4. *The skin-fold of calf showed no relationship to average speed in running during training (r^2=0.124; p>0.05).*

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DISCUSSION AND CONCLUSIONS

We can confirm the findings of Arrese and Ostáriz (2006) that an association between the thickness of calf skin-fold and running performance in long-distance runners exists (figure 1). However, in contrast to their findings, the thickness of thigh skin-fold showed no correlation (figure 2) in our mountain ultra-marathoners. An explanation for this different finding could be the anthropometry of subjects. Body mass in our runners was at 73.0 (7.8) kg compared to 57.98 (5.24) kg of their 10,000 m runners.

Arrese and Ostáriz (2006) found for both front thigh ($r = 0.59$, $p = 0.014$) and medial calf skin-fold ($r = 0.57$, $p = 0.017$) significant correlations with running performance over 10,000 m in male runners. They investigated runners performing races on a flat track where we in contrast investigated mountain ultra-marathoners. Presumably the up- and down-hill running had a different influence on calf skin-fold and thigh skin-fold in these mountain ultra-marathoners compared to track runners.

Legaz and Eston (2005) concluded from their study with high level runners that the decrease in skin-fold thickness is due to intense training. However, we found no relationship between running speed in training and skin-fold thickness at calf (figure 4). Also training volume expressed in average weekly running volume was not associated with skin-fold thickness (figure 3).

Regarding figure 2, we have an outlier with one athlete with a thigh skin-fold of 25 mm. Statistical analysis was re-calculated without this athlete. The r2 for calf skin-fold increased to 0.32 ($p < 0.001$); however, thigh skin-fold again showed no statistical significance ($r2 = 0.06$, $p > 0.05$). Therefore, we did not exclude this outlier since the final result was not changed.

Nine out of our 34 participants (26 %) dropped out due to overuse injuries of the lower limbs between Stage 2 and Stage 5. Regarding training variables, finishers and non-finisher differed in speed in running during training whereas training volume was not different (table 2). We might presume that the non-finishers trained rather intense and probably exaggerated with intensity. However, none of the non-finishers complained about a risk factor of overuse injuries of the lower limbs. According to the literature, risk factors for an overuse injury of the lower limbs are high training loads of more than 60 km per week (Macera, Pate, Powell, Jackson, Kendrick and Craven, 1989), more than 6 training units a week (McKean, Manson and Stanish, 2006), more than 6 races within 12 months (Van Middelkoop, Kolkman, Van Ochten, Bierma-Zeinstra and Koes, 2008), previous lower extremity injury (Hootman, Macera, Ainsworth, Martin, Addy and Blair, 2002) and advanced age (McKean, Manson and Stanish, 2006). The non-finishers reported no overuse injury of the lower limb in the specific preparation for this race and the only difference between finishers and non-finishers was the speed in running during training. We deduce that the higher speed in training was not a reason for the drop out during the ultra-run.

A limitation of the study might be the rather small sample size of included athletes. Unfortunately, the number of participants in ultra-endurance races is rather low compared to contests of shorter distances below or at the marathon distance. The available data is small and statistical power is less than in other studies such as the one performed by Arrese and Ostáriz (2006) with 130 male runners. In contrast to the latter study, the volunteers in this present investigation were part of the participants of the competition with a limited number of participants and the number of subjects was definitely limited to that number. Therefore, the

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power of the current study could not be increased by the number of participants. Arrese and Ostáriz (2006) investigated a total of 130 athletes; however, in their subgroups, smaller sample size of 16 to 24 athletes were analysed. Also Legaz and Eston (2005) investigated the small group of 24 male runners comparable to our study group. Arrese and Ostáriz (2006) had a more homogenous group of subjects compared to our athletes. CV of performance in the male runners in Arrese and Ostáriz (2006) varied between 2.13 % and 3.36 % whereas we had a CV of 14.9 %.

To summarize, we found an association between the thickness of calf skin-fold and total race time in male mountain ultra-marathoners. The relationship of the thickness of calf skin-fold and race performance observed in this investigation seems not to be due to training. It must be assumed that other factors such as genetic determination or diet might be responsible for this association. As Arrese and Ostáriz (2006) already concluded, a longitudinal study is recommended to verify the association between skin-fold thickness at selected sites and running performance.

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