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A PARADIGM FOR IDENTIFYING ABILITY IN COMPETITION: THE ASSOCIATION BETWEEN ANTHROPOMETRY, TRAINING AND EQUIPMENT WITH RACE TIMES IN MALE LONG-DISTANCE INLINE SKATERS – THE 'INLINE ONE ELEVEN'

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ABSTRACT
Purpose. The association between anthropometric and training characteristics on an athlete's performance has been investigated in swimmers, cyclists and runners, but not in inline skaters. The aim of this study was to investigate the relationship between anthropometry, pre race preparation and equipment in the finishers of the longest inline race in Europe, the 'Inline One eleven' over 111 km in Switzerland. **Basic procedures.** We investigated the association of anthropometry, training, and equipment variables with race times in 84 male ultra-endurance inline skaters using bi- and multivariate analysis. **Main findings.** In the multivariate analysis, percent body fat, duration per training unit, and personal best time in the 'Inline One eleven' was related to the race time for all finishers. Out of the 84 finishers, 58 had already finished an 'Inline One eleven' while 26 participated for the first time. Speed in training and the kind of skates worn were related to race times of the 26 inexperienced finishers. The inexperienced finishers skating with custom made skates were significantly faster with 229.1 (12.7) min compared to inexperienced finishers using ordinary skates finishing within 290.8 (35.4) min ($p < 0.001$). For experienced inliners, body mass, the sum of skin-folds and percent body fat correlated to race time. **Conclusions.** We assume that inexperienced athletes in ultra-endurance skating need time to gain the experience necessary in choosing the correct equipment and doing the training in order to successfully finish a long-distance inline race. Experienced inliners can only improve race performance in an ultra-endurance inline race such as the 'Inline One eleven' through a reduction of their body fat.

Key words: skin-fold thickness, body fat, skate shoe, ultra-endurance

Introduction

In endurance athletes, the association between anthropometric variables such as body mass, body height, body mass index, the length and girth of extremities, body fat and skin-fold thicknesses have been investigated mainly in the disciplines of swimming, cycling, running and the triathlon. Body mass was related to the performance of athletes in a 3,000 m steeplechase [1], marathon [2] and ultra-marathon [3]. Apart from runners, body mass also showed a relationship with performance in cyclists, where road cyclists [4] and off-road cyclists [5, 6] with a lower body mass had an advantage in endurance cycling during climbs. Body height seems to be associated with swimming performance, especially in female swimmers, where body height was significantly related to the 100 m freestyle time in girls [7]. In another study, of a 100 yard swim, body height was significantly related to each female swimmer's major competitive stroke [8]. Regarding the length of the swimming distance, body height was related to both short and long-distances in pool swimmers from 50 m to 800 m [9]. Body mass index and endurance performance were negatively correlated to running speed in a 161-km trail run [10]. The relationship of the circumference of limbs with performance has mainly been investigated in runners. The circumference of the upper arms seemed to be related to performance in ultra-endurance runners [3, 11]. In swimmers, the upper extremity length was a predictor variable of 100 m freestyle performances in both boys and girls [7]. Body fat was related to performance in female marathon runners [12], in male ultra-marathoners [13], in female swimmers [8, 14], and in male Ironman triathletes [15, 16]. The association between skin-fold thicknesses and endurance performance was mainly investigated in runners. The total sum of five skin-fold thicknesses was related to performance in male 10 km runners [17] and the sum of seven skin-folds was correlated to marathon performance times [2].

Apart from anthropometry, the volume and intensity in training seem to influence performance in runners. In marathoners, the longest mileage covered per training session was the best predictor for the successful completion of a marathon [18]. Scrimgeour et al. described that runners training more than 100 km per week had sig-

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nificantly faster race times over 10 km to 90 km than athletes covering less than 100 km [19]. Bale et al. demonstrated, in 60 male runners, that elite runners with a higher training frequency, higher weekly training volume and longer running experience had better 10 km performance [17]. Hewson and Hopkins showed a correlation between seasonal weekly duration of moderate continuous running for runners specialising in longer distances [20]. Apart from volume, the running intensity in running was also of some importance. According to Billat et al., top class marathon runners trained for more total kilometres per week, and at a higher velocity, than runners at a lower level [21]. Peak running velocity in training was highly related to 5 km run times for both male and female athletes [22]. In ultra-endurance swimmers, speed in training was related to race performance in a 26.4 km open-water ultra-swim [23]. In addition to training, pre race experience was also associated with endurance performance, as described for Ironman triathletes. Gulbin and Gaffney described that the previous best performances in an Olympic distance triathlon, coupled with weekly cycling distances and longer training rides, could partially predict overall Ironman race performances [24]. Also, in recent studies investigating ultra-runners, a personal best marathon time was related to performance in a 24 hour run [25] and with race times in both a 100 km ultra-marathon [26] and multi-stage mountain ultra-marathon [27].

The sports discipline of inline speed skating is a special endurance discipline with a technical aspect. Inline skaters use special skates where the number, size and hardness of the wheels can be changed and may affect performance. Before each race the athletes assemble their skates as dictated by the race course. Also, these athletes can use ordinary skates or custom made skates, and these skates can be differentiated by the wheel bearing used. Apart from anthropometry, training and pre race experience, the kind of skates might be differently related to performance in long-distance inline skaters.

The aim of this study was to investigate the association of anthropometry, training, and equipment variables with race times in the longest inline marathon in Europe, the ‘Inline One eleven’ in Switzerland. Since inline skaters use skates that can be adjusted by the kind of skates (ordinary skates or custom made skates), the kind of wheel bearing (small or large) and the size, number and hardness of wheels, we also took these variables as well as the anthropometry and training variables into consideration. We hypothesized also that in long-distance inliners like in other endurance disciplines, both of anthropometry and training variables would be related to performance.

Material and methods

The organiser of the ‘Inline One eleven’ in St. Gallen, Switzerland contacted all the participants of the race via a separate newsletter upon joining the 2009 race, the 12th year of this event. The ‘Inline One eleven’ was the longest inline skating race in Europe, covering a total distance of 111 km with a total altitude of 1,400 m to climb. The start of the race was in the heart of the City of St. Gallen, and then went on a large loop of 111 km in the East of Switzerland returning to St. Gallen. Inliners from all over Europe came to St. Gallen for the longest inline race in Europe, held on completely closed routes.

Subjects

A total of 92 male athletes volunteered for this study. They all gave their written informed consent. The study was approved by the local Institutional Ethics Committee of the Canton St. Gallen, Switzerland. The athletes came on Saturday 15th August 2009 to get their race numbers and instructions for the race. On 16th August 2009 at 07:00 a.m., the race started. During the 111 km, the organizer offered 11 refreshment points including an opportunity to repair their skates in case of a malfunction. Split times and total race time were measured using an electronic chip system.

Procedures

The day before the start of the race the subjects’ body mass, body height and thickness of skin-folds (pectoralis, axillar, triceps, subscapular, abdomen, suprailiac, thigh and calf) were measured. With this data, body mass index, the sum of eight skin-folds and percent body fat were calculated. 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 0.5 cm. Skin-fold data was obtained using a skin-fold caliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) and recorded to the nearest 0.2 mm. One trained investigator took all the measurements as inter-tester variability is a major source of error in skin-fold measurements. All skin-fold thicknesses were determined on the right side of the body in all the athletes. The skin-fold measurements were taken three times and the mean was then used for the analyses. The skin-fold measurements were standardized to ensure reliability and readings were performed 4 s after applying the caliper, according to Becque et al. [28]. An intra-tester reliability check was conducted on 27 male runners prior to testing. No significant differences between the two trials for the sum of skin-folds were observed ($p > 0.05$). The intra-class correlation (ICC) was high at $r = 0.95$. The same investigator was also compared to another trained investigator to determine objectivity. No significant differences were found between the testers [29]. Percent body fat was calculated using the following anthropometric formula according to Ball et al. [30]: Percent body fat = $0.465 + 0.180(\Sigma 7SF) - 0.0002406(\Sigma 7SF)^2 + .0661(age)$, where Σ7SF = sum of skin-fold 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.

Upon their inclusion in the study, and until the start of the race, the athletes were asked to maintain a comprehensive training diary recording training sessions showing the distance and duration in preparing for the race. The training record consisted of the number of weekly training units in inline skating, showing duration, kilometres and pace. Furthermore, they reported on the number of years they had been active inliners, including participation in inline races, as well as the number of completed 'Inline 111' races, including their personal best time for that course.

Statistical analysis

The Shapiro-Wilk test was used to check for normality distribution. Data is presented as mean and standard deviation (SD). The athletes were categorized into groups such as finishers and non-finishers, and finishers who had completed an 'Inline One eleven' race (experienced) and finishers who had not completed one (inexperienced). Parameters of age, anthropometry, pre race experience, training and skates were compared between these groups using the Kruskal-Wallis equality-of-populations rank test. The coefficient of variation of performance (CV % = 100 × SD/mean) for total race time was calculated. Race time was also expressed as a percentage of the course record. In order to reduce the variables for the multiple linear regression analysis, bivariate correlation analysis between the mentioned variables body mass, body height, body mass index, circumference and length of limbs, body fat, sum of skin-folds, skin-fold thickness at thigh and calf, volume and intensity in training, personal best time and race time were performed using the Pearson correlation analysis. Multiple regression analysis was then used to investigate predictor variables for race time including significant variables after the bivariate analysis. A power calculation was performed according to Gatsonis and Sampson [31]. To achieve a power of 80% (two-sided Type I error of 5%) to detect a minimal correlation between race time and anthropometric variables of 20% (i.e. coefficient of determination $R^2 = 0.2$) a sample of 40 participants was required. An alpha level of 0.05 was used to indicate significance.

Results

A total of 651 male inliners started in the 'Inline One eleven' in 2009, and 611 male athletes (94%) arrived at the finish within the time limit of 10 hours. A total of 92 male study participants started in the race, 84 subjects (91%) finished. The finishers completed the 111 km within 264 (41) min (CV = 15.6%), equal to 4:15 (0:41) h:min. The athletes were skating at an average speed of 25.8 (4.0) km/h. Expressed as a percentage of the overall course record, of 3:07 h:min by Tristan Loy (F) in 2003, the subjects completed within 144 (22) %. Among the eight non-finishers, three skaters had to stop due to problems with their locomotor system; five gave up due to exhaustion. No athlete suffered an accident and no athlete complained about having a problem with his inline skates.

Table 1 represents the age and anthropometric variables of the eight non-finishers and the 84 finishers and the association between the variables with race time for successful finishers using bivariate analysis. The eight non-finishers were taller and had longer extremities than the 84 finishers. Age, body mass, body mass index, circumference of limbs, skin-fold thickness of the lower body, the sum of skin-folds and percent body fat were related to the race times of finishers. Regarding training and pre race experience, no differences were found between non-finishers and finishers (see Tab. 2). For finishers, both the duration and speed per training unit and the personal best time in an 'Inline One eleven' race were related to race time in the bivariate analysis. Non-finishers and finishers showed no differences regarding their skates and wheels (see Tab. 3). The kind of skates and the size of the wheels used were related to the race time for the finishers. When we inserted the significant variables after the bivariate analysis for all finishers in the multiple linear regression analysis, percent body fat, duration per training unit, and personal best time in an 'Inline One eleven' were related to race time (see Tab. 4).

Table 1. Comparison of age and anthropometry between finishers and non-finishers and the association between variables with race time for finishers. Values are given as mean (SD). * = $p < 0.05$, ** = $p < 0.01$. p-value is given in case of a significant correlation

Age and anthropometry	Non-Finisher (n = 8)	Finisher (n = 84)	r
Age (y)	41.3 (11.0)	40.7 (10.2)	0.30, p = 0.0056
Body height (m)	1.87 (0.09)	1.77 (0.06)*	0.17
Body mass (kg)	83.6 (12.0)	75.9 (9.6)	0.42, p < 0.0001
Body mass index (kg/m^2)	23.8 (2.3)	24.1 (2.7)	0.35, p = 0.0011
Length of leg (cm)	91.6 (5.5)	86.7 (4.5)*	0.04
Length of arm (cm)	85.9 (2.7)	81.3 (4.0)**	0.10
Circumference upper arm (cm)	29.4 (1.4)	30.1 (2.3)	0.32, p = 0.0026
Circumference thigh (cm)	56.7 (2.9)	56.2 (3.0)	0.29, p = 0.0067
Circumference calf (cm)	39.7 (2.6)	38.3 (2.3)	0.38, p = 0.0004
Skin-fold front thigh (mm)	15.1 (6.9)	13.3 (6.9)	0.22, p = 0.0484
Skin-fold medial calf (mm)	6.4 (3.0)	6.2 (2.8)	0.27, p = 0.0119
Sum of eight skin-folds (mm)	101.5 (47.8)	91.3 (36.3)	0.43, p < 0.0001
Percent body fat (%)	17.7 (5.2)	16.4 (4.8)	0.45, p < 0.0001

Table 2. Comparison of training parameters between finishers and non-finishers and the association between training variables with race time in finishers. p-value is given in case of a significant correlation

Experience and training	Non-Finisher (n = 8)	Finisher (n = 84)	r
Years as active inliner	6.1 (3.5) (n = 8)	7.6 (3.6) (n = 78)	0.07
Number of weekly training units in inline skating	1.8 (0.9) (n = 8)	2.6 (3.3) (n = 80)	–0.14
Distance per training unit in inline skating (km)	31.0 (11.6) (n = 8)	31.4 (9.0) (n = 80)	0.14
Duration per training unit in inline skating (min)	86.2 (34.5) (n = 8)	97.2 (28.0) (n = 80)	0.33 p = 0.0031
Speed in inline skating during training unit (km/h)	23.4 (4.1) (n = 8)	22.7 (4.8) (n = 80)	–0.46 p < 0.0001
Number of finished 'Inline One eleven'	2.5 (1.7) (n = 4)	3.5 (2.7) (n = 58)	0.04
Personal best time at 'Inline One eleven' (min)	288 (49) (n = 4)	257 (36) (n = 58)	0.71 p < 0.0001

Table 3. Comparison of skates and wheels between finishers and non-finishers and the association between training variables with race time in finishers. p-value is given in case of a significant correlation

Skates and wheels	Non-Finisher (n = 8)	Finisher (n = 84)	r
Kind of skates			0.57, p < 0.0001
Ordinary skates	6	54	
Custom made skates	2	30	
Wheel bearing			–0.17
Small	3	15	
Large	5	69	
Size of wheels			–0.46, p < 0.0001
80 mm		3	
82 mm		1	
84 mm	2	3	
90 mm		1	
100 mm	4	53	
104 mm		1	
110 mm	2	22	

Skates and wheels	Non-Finisher (n = 8)	Finisher (n = 84)	r
Number of wheels per skate			0.10
4	7	79	
5	1	5	
Hardness of wheels			–0.10
82	1	6	
83	1	5	
84	1	12	
85	3	31	
86	1	25	
87		2	
88		1	
90	1	2	

Table 4. Multiple linear regression analysis with race time as the dependent variable for finishers (n = 84) using all significant variables after bivariate analysis. β = regression coefficient; SE = standard error of the regression coefficient; coefficient of determination (R^2) of the model was 75%. Twenty-six finishers had not completed at least one 'Inline One eleven' before this race

	β	SE	p
Body mass	1.55	0.64	0.021
Body mass index	–4.29	2.80	0.13
Circumference of upper arm	2.39	3.0	0.43
Circumference of thigh	–0.23	2.01	0.90
Circumference of calf	–0.28	2.49	0.90
Skin-fold of front thigh	–1.16	0.81	0.16
Skin-fold of medial calf	1.46	2.01	0.46
Sum of eight skin-folds	–1.22	0.64	0.06
Percent body fat	11.34	4.64	0.019
Duration per training unit in inline skating	0.33	0.13	0.019
Speed in inline skating during training unit	0.47	0.80	0.56
Personal best time in an 'Inline One eleven'	0.47	0.12	0.0005
Kind of skates	14.51	8.31	0.08
Size of wheels	0.002	0.62	0.99

Table 5. Multiple linear regression analysis with personal best time as the dependent variable for finishers (n = 58) using all significant variables after bivariate analysis. Variables of skates and wheels were excluded since inline skaters assemble their shoes according to the race. β = regression coefficient; SE = standard error of the regression coefficient; coefficient of determination (R^2) of the model was 45%

	β	SE	p
Body mass	1.05	0.81	0.19
Body mass index	–5.98	3.44	0.08
Circumference of upper arm	6.92	3.67	0.06
Circumference of thigh	–1.42	2.59	0.58
Circumference of calf	5.62	3.07	0.07
Skin-fold of front thigh	–0.24	1.03	0.81
Skin-fold of medial calf	3.43	2.52	0.18
Sum of eight skin-folds	–1.61	0.79	0.047
Percent body fat	12.59	5.59	0.029
Duration per training unit in inline skating	–0.01	0.15	0.91
Speed in inline skating during training unit	0.07	1.03	0.93

The personal best time in an 'Inline One eleven' showed the highest correlation, and we performed a separate regression analysis with personal best time in an 'Inline One eleven as a dependent variable for the 58 experienced athletes who had already completed at least one 'Inline One eleven' (see Tab. 5). Inexperienced and experienced finishers were compared in Table 6. The inexperienced finishers had longer arms, but showed no other differences regarding anthropometry, training or pre race experience compared to the experienced finishers. When we compared inexperienced finishers and experienced inliners regarding the association of variables with race time, the speed in training and the kind of skates worn were related to race time in inexperienced finishers (see Tab. 7). Inexperienced finishers with custom made skates were significantly faster, with 229.1 (12.7) min, compared to inexperienced inline skaters using ordinary skates and finishing within 290.8 (35.4) min (p < 0.001). For experienced inliners, body mass, the sum of skin-folds and percent body fat correlated to race time (see Tab. 8).

Discussion

The aim of this study was to investigate the association between the variables of anthropometry, training, and equipment with race times in the longest inline marathon in Europe, the 'Inline One eleven' in Switzerland. Regarding existing literature on other endurance disciplines, we hypothesized that for these long-distance inliners, as

Table 6. Comparison of age, anthropometry and training between inexperienced and experienced inliners who had already finished at least one 'Inline One eleven'. * = $p < 0.05$

Age and anthropometry	Inexperienced finishers ($n = 26$)	Experienced finishers ($n = 58$)
Age (y)	37.8 (8.8)	41.9 (10.6)
Body height (m)	1.79 (0.05)	1.77 (0.07)
Body mass (kg)	76.1 (8.4)	75.9 (10.2)
Body mass index (kg/m^2)	23.6 (2.3)	24.2 (2.9)
Length of leg (cm)	87.2 (3.4)	86.4 (4.9)
Length of arm (cm)	82.6 (3.8)*	80.6 (4.0)
Circumference upper arm (cm)	29.8 (2.3)	30.2 (2.3)
Circumference thigh (cm)	55.9 (2.8)	56.4 (3.0)
Circumference calf (cm)	38.3 (2.0)	38.3 (2.4)
Skin-fold front thigh (mm)	12.7 (7.6)	13.6 (6.7)
Skin-fold medial calf (mm)	6.3 (3.1)	6.2 (2.6)
Sum of eight skin-folds (mm)	85.2 (32.6)	94.0 (37.9)
Percent body fat (%)	15.5 (4.2)	16.9 (5.0)
Years as active inliner	6.7 (3.6)	8.0 (3.6)
Number of weekly training units in inline skating	2.2 (0.8)	2.8 (4.0)
Distance per training unit in inline skating (km)	31.8 (8.8)	31.2 (9.1)
Duration per training unit in inline skating (min)	102.5 (28.8)	95.0 (27.6)
Speed in inline skating during training unit (km/h)	21.4 (4.9)	23.3 (4.7)
Race time (min)	274.3 (41.5)	259.7 (40.7)
Ordinary skates	19	35
Custom made skates	7	23

Table 7. Multiple linear regression analysis with race time as the dependent variable for inexperienced finishers ($n = 26$) using all significant variables after bivariate analysis. β = regression coefficient; SE = standard error of the regression coefficient; coefficient of determination (R^2) of the model was 90%

	β	SE	*p*
Body mass	–2.32	1.30	0.10
Body mass index	–7.41	7.65	0.35
Circumference of upper arm	3.99	4.12	0.35
Circumference of thigh	4.42	3.95	0.28
Circumference of calf	7.57	3.51	0.05
Skin-fold of front thigh	–0.95	1.44	0.52
Skin-fold of medial calf	–3.00	3.46	0.40
Sum of eight skin-folds	1.20	1.11	0.30
Percent body fat	–4.06	8.22	0.63
Duration per training unit in inline skating	–0.09	0.21	0.65
Speed in inline skating during training unit	–4.90	1.06	0.0010
Kind of skates	29.62	11.91	0.0322
Size of wheels	–1.24	0.64	0.08

Table 8. Multiple linear regression analysis with race time as the dependent variable for experienced inliners in 'Inline One eleven' ($n = 58$) using all significant variables after bivariate analysis. β = regression coefficient; SE = standard error of the regression coefficient; coefficient of determination (R^2) of the model was 66%

	β	SE	*p*
Body mass	1.92	0.73	0.0124
Body mass index	–6.11	3.17	0.06
Circumference of upper arm	4.76	3.38	0.16
Circumference of thigh	–0.76	2.30	0.74
Circumference of calf	2.03	2.77	0.46
Skin-fold of front thigh	–1.07	0.93	0.25
Skin-fold of medial calf	2.60	2.28	0.26
Sum of eight skin-folds	–1.78	0.72	0.0185
Percent body fat	15.73	5.16	0.0040
Duration per training unit in inline skating	0.24	0.15	0.11
Speed in inline skating during training unit	0.51	0.92	0.57
Kind of skates	16.3	9.5	0.09
Size of wheels	–0.70	0.68	0.31

in other endurance athletes, both anthropometry and training variables would be related to performance.

Considering the whole sample of 84 participants, the personal best time in the 'Inline One eleven' showed the highest association with race time, apart from body mass, percent body fat and duration per training unit in inline skating. When we investigated, separately, the 58 experienced inliners who had already performed at least one 'Inline One eleven', anthropometric variables such as the sum of skin-folds and percent body fat were related to race time. For the 26 inexperienced finishers, speed in training and the kind of skates worn were associated with race time. We must therefore assume that beginners in long-distance skating rely more upon technical equipment, whereas experienced long-distance skaters already know their equipment and their long-distance performance relies more upon body composition such as body mass, skin-fold thickness and body fat.

The relationship of the physical characteristics such as body mass [1–6, 26, 32], body fat [3, 13, 15, 16, 26] and skin-fold thicknesses [17, 32–36] with endurance performance has mainly been investigated in runners, cyclists and triathletes. The finding that body fat was related to ultra-endurance performance in these athletes confirms the recent findings of Hoffmann et al. [13]. They described a significant and positive correlation between percent body fat and finish time for male ultra-marathoners in a 161-km trail ultra-marathon. However, regarding ultra-marathoners during a 100 km run, percent body fat was not related to race time [26]. Also in a 24-hour run, body fat showed no association with performance [25]. The correlation between both the sum of skin-fold thicknesses and single skin-folds with endurance performance has mainly been investigated in runners where studies over distances from 100 m to ultra-endurance had been performed. In male 10 km runners, the total sum of five skin-fold thicknesses was related to performance [17]. In marathoners, the sum of seven skin-folds was correlated to marathon performance times [2]. The length of a running performance may determine whether skin-fold thicknesses are related to performance. In male ultra-endurance runners during a 24 hour run, skin-fold thicknesses showed no association with performance [25] and also during a 100 km run, the sum of skin-folds was not associated with race performance [26]. The kind of performance seems to also influence this correlation. In cyclists, no correlation between skin-fold thicknesses and race performance has been found; neither in ultra-endurance road cyclists [34], nor in ultra-endurance mountain-bikers [36]. However, in ultra-endurance triathletes competing in distances longer than the Ironman distance, the sum of eight skin-fold thicknesses was related to race performance [35].

In the bivariate analysis, the duration and speed in inline skating during training and the personal best time in an 'Inline One eleven' were related to race times for all finishers. In the multivariate analysis, duration in inline skating during training and personal best time in an 'Inline One eleven' remained significant. When we compared inexperienced and experienced inliners in the 'Inline One eleven' we found no differences regarding training. However, speed in inline skating during training was related to race time for inexperienced finishers in the multivariate analysis. We must assume that training especially in the case of inexperienced finishers is, apart from equipment, an important determinant for race success in long-distance inline skating. McKelvie et al. [37] described that training pace was important in runners where faster workouts were associated with faster marathon times. Also Billat et al. [21] concluded that top class marathon runners trained for more total kilometres and at a higher velocity when compared to high-level marathon runners.

In the bivariate analysis, the kind of skates and the size of wheels were related to race time for all finishers. In the multivariate analysis with all finishers, equipment was no longer associated with race time. When we separately analysed inexperienced and experienced inliners, the kind of skates worn was associated with race times for inexperienced finishers in the multivariate analysis. Obviously, the skates of the inexperienced finishers were responsible for the significant association found in the bivariate analysis. Inliners can buy ordinary skates in the shop or order custom made skates to exactly fit the athlete's feet. Twenty-seven percent of the rookies wore custom made skates, whereas 40% of the experienced inliners had custom made skates; those inexperienced finishers with custom made skates were significantly faster compared to the inexperienced finishers with ordinary skates. We can compare the correlation of footwear for these inliners with the results of studies done on runners. In runners, increasing the shoe suppleness increased sprint performance [38]. Furthermore, athletic footwear affects the balance in athletes [39]. Athletes with adequate shoes have better balance, which is important in inline skating. Furthermore, athletic footwear can have a much larger influence on performance by minimizing a loss of energy [40].

Conclusions

To summrise, we found that in these ultra-endurance inline skaters anthropometry, training and pre race experience such as the personal best time in the 'Inline One eleven' were associated with race times for all finishers, where the personal best time in the 'Inline One eleven' showed the highest correlation. When experienced athletes were compared to inexperienced finishers, the kind of skates worn and the speed in training was associated with the race time for inexperienced finishers, whereas the sum of skin-folds and percent body fat was related to race time in experienced finishers. We assume that inexperienced finishers need time to gain the appropriate amount of experience in using the correct equipment, and to complete the difficult training in order to successfully finish a long-distance inline race. Experienced inliners using the appropriate equipment can only improve their race performance with a decrease in body fat.

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