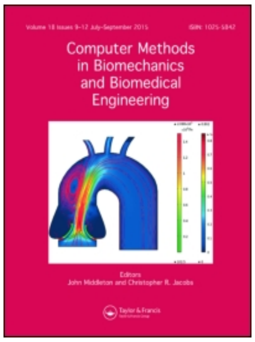

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Postural position and architectural foot modifications during Mountain Ultra-Marathon

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KEYWORDS Mountain ultra-marathon; foot; posture; plantar pressure; podiatry

1. Introduction

Long distance races increase the risk of injury to runners including fatigue fractures (Nagel et al. 2008). The body undergoes modifications in particular during the Mountain Ultra-Marathon (MUM) by increasing the displacement of the center of pressure on the antero-posterior and medio-lateral axis (Degache et al. 2014). The analysis of muscular response at UTMB® shows a modification to a voluntary contraction of knee extensors and plantar flexors of feet (Millet et al. 2011; Giandolini et al. 2016). These data provide biomechanical changes in the pitch frequency, contact time and knee or ankle joint angles after the same effort (Giandolini et al. 2013; Degache et al. 2016).

The objective of this study is therefore to evaluate, throughout a MUM, the changes in the position of the center of gravity, the pre-foot pressure and the overall foot architecture.

2. Methods

2.1. Population

A hundred UTMB® runners, 171 km and 10000 m of ascending elevation, (43.3 ± 8.8 yrs, 1.77 ± 0.07 m, 71.6 ± 9.6 kg) maintained a standing position erected for 51.2 seconds (AFP Norm) at different points of refuelling: Chamonix (km 0, n=100), Chapieux (km 49, n=29), Courmayeur (km 79, n=11), Champex (km 124, n= 23), Chamonix (km 171, n=38).

2.2. Experimental Protocol

When each runner arrived at the checkpoint, he must maintain a standing position in the standard position (AFP standard) for 51.2 s. Before recording, the length and width of the front feet were measured in this same position while the rider evaluates his fatigue.

2.3. Measures

The mean position of Center Of Pression (COP) on Y and X axis and the percent of the weight of the forefoot (FFP) averaged between the two feet, were determined from a Fusyo stabilometry platform (Medicapteurs®, Balma, France) at 40 Hz.

The width of the feet (WFF) was determined between the 1st and the 5th metatarsal head (Teyhen et al. 2009) by an electronic calliper graduated in mm (Dexter, Lille, France).

The length of each foot (LOP) was measured using a rule graduated in mm (Kapro, Lake Mills, USA) equipped with a cursor placed at the most anterior point of the foot (Teyhen et al. 2009).

A graded scale of fatigue of 6 to 20 (Borg 1982) evaluated the global state of exhaustion.

2.4. Statistical analyses

All the architectural data (LOF and WFF), fatigue scale, and stability (Y mean and X mean) and posturographic

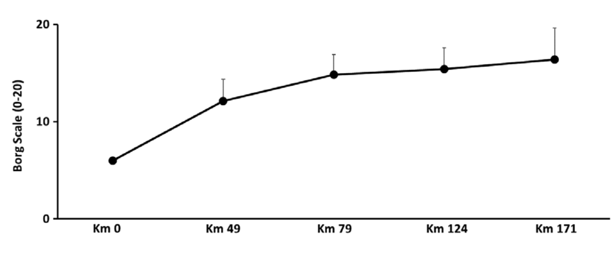

Figure 1. Evolution of fatigue during an Mountain Ultra-Marathon.

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Table 1. Summary of data during MUM (significant effect with: a km 0, b km 49, c km 79, d km 124; p < 0,05).

Data studied		Chamonix km 0	Chapieux km 49	Courmayeur km 79	Champex km 124	Chamonix km 171
Borg Scale		6	12.1 ± 2.2 [a]	14.8 ± 2.1 [a,b]	15.4 ± 2.2 [a,b]	16.4 ± 3.2 [a,b]
Lenght of foot (mm)	Right	265.9 ±13.2	269.2 ± 13.5	271.3 ± 9.5	269.6 ± 9.9	267.2 ± 12.1
	Left	267.8 ±13.8	270.9 ±12.4	273 ± 8.7	271.1 ± 11.1	269.3 ± 12.7
Width of foot (mm)	Right	103.2 ± 6.1	103.1 ± 4.9	108.4 ± 3.3 [a,b]	108.9 ± 4.2 [a,b]	106.7 ± 5.2 [a,b]
	Left	103.4 ± 6.2	104.1 ± 4.7	107.3 ± 3.8 [a,b]	107.2 ± 4.3 [a,b]	106.6 ± 4.8 [a,b]
Y mean (mm)		-37.1 ± 15.1	-29.3 ± 11.7 [a]	-19.3 ± 11.3 [a]	-30.3 ± 13.9 [a]	-20.3 ± 14.43 [a]
X mean (mm)		-2.1 ± 6.1	-1.3 ± 6.5	-2.2 ± 4.9	-0.28 ± 6.4	-4.4 ± 7.4
Front foot plantar pressure (% of BW)		47.4 ± 7.9	50.3 ± 5.5 [a]	54.8 ± 3.34 [a]	50.3 ± 5.3 [a]	50.2 ± 7.9 [a]

data (FFP) were tested from Wilcoxon's nonparametric test throughout the course of the race. A correlation coefficient was calculated by the Spearman test to determine the degree of linear relationship between all variables. The level of significance for all tests was set at the 5% threshold.

3. Results and discussion

The fatigue scale shows a significant increase in the feeling of fatigue between departure and km 50 ($p<0.01$) and between km 50 and km 80 ($p<0.05$) where it reaches its maximum and does not change until arrival.

The length of the right foot and the left foot does not change during the whole race.

WFF right and WFF left did not change significantly between the start and Chapieux, then widened significantly in Courmayeur ($p<0.01$) and then did not change until arrival.

The mean position of the CDP on the antero-posterior axis (Y) shows a progression between the point km 0 and 50 ($p<0.01$) and then stabilizes in this advanced position, without changing, until the end.

The average position of the CDP on X does not change during the race.

The overall plantar pressure of both feet showed a significant increase between departure and Chapieux ($p<0.01$) and then stabilized throughout the race.

Spearman tests revealed a weak relationship between Width left foot and width right foot ($r=0.55$, $p<0.05$) and between Y mean and front foot plantar pressure ($r=0.5$, $p<0.05$).

These results show that the modification of the posture shows an offset towards the front of the center of pressure correlated with an increase in the forefoot plantar pressure. This plantar pressure, under the forefoot, remaining more important during the race, could partly explain the increase in stresses under this zone that can cause stress fractures (Nagel et al. 2008).

The overall foot architecture showing an increase in the width of the foot after 50 km also shows the importance of this foot zone. The non-modification of the length of the foot goes against the classical thoughts of the riders who should perhaps favour the increase of the width of the feet (Blenkinsopp et al. 2012) rather than the length.

4. Conclusions

Through this study, we notice that the postural modification is a factor to be considered during a MUM as well as the increase in the width of the feet for a preventive and performance purpose.

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