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# Evolution of perceived footwear comfort over a prolonged running session

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## HIGHLIGHTS

- The perceived overall footwear comfort decreased over prolonged trail running at race speed.
- The change in overall footwear comfort therefore indicated a clinically relevant deterioration in footwear comfort over time.
- This decrease was not proportional to time and became significant only after 44 min of running or 7.8 km.
- Judgement based on perception could then be skewed by fatigue independently of the actual footwear comfort.

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## ABSTRACT

*Background:* The purpose of this study was to investigate the subjective perception of overall footwear comfort over a prolonged running session.
*Methods:* Ten runners performed two similar sessions consisting of a 13-km trail run (5 laps of 2.6 km) as fast as possible. The overall footwear comfort was evaluated before running and at the end of each lap with a 150-mm visual analogic scale, as well as speed, heart rate and rate of perceived exertion.
*Results:* The results showed that both overall footwear comfort and speed decreased consistently during the run session, and significantly after 44 min of running (*i.e.* the 3rd lap). It could be hypothesized that the deterioration of overall footwear comfort was explained by mechanical and energetical parameter changes with time and/or fatigue occurring at the whole body, foot and footwear levels.
*Conclusion:* These results justify the use of a prolonged running test for running footwear comfort evaluation.



## 1. Introduction

Footwear comfort is one of the most important factors for sport footwear manufacturers. Many studies have focused on developing a reliable method to assess footwear perceived comfort [1–4]. The continuous visual analogic scale (VAS) has been proven to be a reliable measure of subjective footwear comfort. The end-points of the VAS must be clearly delineated (*e.g.* the left end labelled "not comfortable at all" and the right end "most comfortable condition imaginable"), and the optimal length was 100 or 150 mm [3,4]. The ratio scale property of the VAS will allow quantification of the difference in comfort between two or more footwear conditions. An important indicator has been calculated from the VAS: the minimal clinically important difference in rating scales (MCID), *i.e.* the smallest difference in a score that subjects perceive to be beneficial [3]. When fitting footwear overall, a clinically meaningful change in comfort is achieved when a 8.28-mm change on the 100-mm VAS is achieved. The experimental design is also very important. Mündermann et al. [4] were the first to validate an experimental method to evaluate and to compare overall footwear comfort during running. They showed that (i) a control condition must be included with the footwear tested, (ii) subjects with low repeatability must be excluded and (iii) four to six sessions are necessary. More recently, Mills et al. [3] recommended two sessions without a control condition for reliable overall footwear comfort measures during both 2-min walking and running.

*Abbreviations:* VAS, visual analogic scale; MCID, minimal clinically important difference in rating scales; OFC, overall footwear comfort; RPE, rate of perceived exertion; $RPE_{max}r$, ate of perceived exertion measured at the end of the running test; $HR_{lap0}$, heart rate measurements before running; $HR_{max}$, heart rate measurements at the end of the running test.

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However, a number of questions remain, including the changes in perceived footwear comfort over the time spent doing the physical activity, and with the possible emergence of fatigue in repeated trials. It can be expected that the perception of footwear comfort will vary during a prolonged physical activity with the subjects' fatigue, the thermal and mechanical stress on the foot, and the footwear aging. As a consequence, the footwear comfort measured at rest or at the beginning of physical exercise may not correspond to that measured during physical exercise or at exhaustion. This question is crucial since numerous physical activities are executed over long periods and the footwear must remain comfortable throughout.

To our knowledge, no studies have examined overall footwear comfort over time during physical activity. Only Gonzales et al. [5] evaluated both the subjective perception of footwear thermal comfort and the footwear humidity over a 20-min walking session. They showed that subjects were able to perceive a humidity difference over time. In contrast, comfort over time has been evaluated during prolonged use of everyday equipment such as the seat. It has been found that mean seat comfort ratings decrease as the sitting position duration increases, with the appearance of discomfort after 3 h [6]. The authors concluded that the time necessary to experience the onset of discomfort was a reliable discriminating parameter in evaluating changes in comfort over time. The question must be raised, therefore, of whether perceived footwear comfort could also vary depending on the time spent running. The purpose of this study was to assess the perceived footwear comfort over time during a longer running test. The hypothesis was that the perceived footwear comfort changed along a prolonged running exercise.

## 2. Methods

### 2.1. Participants

Ten regular trail runners ($21.1 \pm 1$ yr; $1.77 \pm 0.06$ m; $70.7 \pm 7.4$ kg) participated in this study. They were fully informed of the study conditions and gave written informed consent with the University Ethics Committee before participating.

### 2.2. Experimental procedure

Each participant performed two similar sessions (*i.e.* test/retest protocol) 1 week apart. Daytime, weather, environmental temperature and field characteristics were almost identical for the two sessions. At the beginning of each session, each subject warmed up individually by running during at least 5 min at moderate intensity. Then, the subject ran five 2.6-km laps (total 13 km) consisting of flat, uphill and downhill sections similar to a trail course (land, stones). The speed at the start corresponded to each individual maximum speed race for performing this 13-km run. It was 12.3 km $h^{-1}$ on average at the start and ranged between 14.4 to 11.2 km $h^{-1}$.

### 2.3. Equipments and data measurements

- The same model of new trail running footwear was imposed for all subjects (XT Wings, Salomon SAS, Annecy, France), with individually adapted shoe size. Each subject ran earlier with its new pair of shoe during 10 km during the week before the test.
- A VAS was used to evaluate subjective overall footwear comfort (OFC). Subjects had to answer the question "What is the degree of overall comfort perceived in your footwear?" by ticking a 150-mm analogue scale with the left end labelled "not comfortable at all" (0 comfort points) and the right end "most comfortable condition imaginable (150 comfort points) [4]. OFC was evaluated before the running test (lap 0), at the end of each lap during a 15-s slow walking period (lap 1 to lap 4) and at the end of the running test (lap 5). The value of 12.4 mm was used to identify the MCID in footwear comfort for the present 150-mm VAS, adjusting proportionately the value of 8.3 mm calculated by Mills et al. [3] for a 100-mm VAS. The present proportional adjustment can however be source of error.
- Exercise intensity was estimated subjectively and physiologically by, respectively, both a rate of perceived exertion (RPE; with a 6–20 Borg's scale [7]) measured at the end of the running test ($RPE_{max}$) and by heart rate measurements (cardiofrequencemeter Polar, Kempele, Finland) before running and at the end of the running test ($HR_{lap0}$ and $HR_{max}$).
- Run time per lap was recorded with a chronometer in order to calculate the runner's speed during each lap (in m $s^{-1}$).

### 2.4. Statistical analysis

Means and standard deviations (±SD) were calculated for each variable. The Shapiro–Wilk test proved all variables to be normally distributed. Intraclass correlation coefficients (ICC type (3, 1); [8].) calculated from the two sessions was used to check the measurement reliabilities of OCF, speed, $RPE_{max}$, $HR_{lap0}$ and $HR_{max}$ parameters. A two-factor ANOVA for repeated measures was used to analyse the influence of the sessions and the duration of the run on OCF and speed values, followed by a *post-hoc* Scheffé test. Student's *t*-test was also used to compare $HR_{lap0}$ and $HR_{max}$ data, *i.e.* to test the influence of the duration of the run, within each session. Finally, the relationships between OCF on one hand and $RPE_{max}$, $HR_{lap0}$, $HR_{max}$ on the other hand were tested by the Pearson product moment correlation coefficient. Except for ICC calculation, the level of significance was set at $P < 0.05$.

## 3. Results

ICC coefficients for inter-session repeatability were 0.737 for OFC, 0.576 for speed, 0.760 for $HR_{lap0}$, 0.641 for $HR_{max}$ and 0.530 for $RPE_{max}$ parameters.

The run lasted $80.7 \pm 9.8$ min and $78.4 \pm 9.2$ min during sessions 1 and 2, respectively. Lap speed (mean ± SD) is presented in Table 1 for both sessions. Speed did not differ between sessions

**Table 1**
Temporal, physiological and perceptual variables measured during each lap of the running test during both sessions. Values are expressed as means ± SD.

| | | Lap 0 | Lap 1 | Lap 2 | Lap 3 | Lap 4 | Lap 5 |
|---|---|---|---|---|---|---|---|
| Speed (m $s^{-1}$) | S1 | | 3.6 ± 0.39 | 3.01 ± 0.33 | 2.67 ± 0.28 | 2.56 ± 0.41 | 2.42 ± 0.35 |
| | S2 | | 3.26 ± 0.42 | 2.97 ± 0.22 | 2.76 ± 0.16 | 2.76 ± 0.26 | 2.58 ± 0.31 |
| OFC (mm) | S1 | 116.1 ± 23.1 | 108.4 ± 18.8 | 105.5 ± 20.2 | 92.4 ± 24.5 | 85.8 ± 19.4 | 73.4 ± 20.3 |
| | S2 | 119.5 ± 21.0 | 111.0 ± 19.1 | 102.8 ± 16.5 | 95.8 ± 18.1 | 88.0 ± 19.3 | 86.9 ± 26.5 |
| HR (bmp) | S1 | 75.2 ± 6.3 | | | | | 188.1 ± 7.8 |
| | S2 | 76.6 ± 5.1 | | | | | 187.0 ± 11.3 |
| RPE (s.u.) | S1 | | | | | | 16.0 ± 0.8 |
| | S2 | | | | | | 15.1 ± 0.7 |

S1: session 1; S2: session 2; OFC: overall footwear comfort; HR: heart rate; RPE: rate of perceived exertion.