PHYSIOLOGICAL AND SUBJECTIVE EVALUATION OF FOOTWEAR THERMAL RESPONSE OVER TIME

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INTRODUCTION

This paper presents a novel methodology to evaluate footwear thermal comfort over time. A preliminary study was carried out to assess the validity of the test. Two different kinds of footwear were tested and physiological and subjective data was registered during the experiments on diverse foot zones over time. Significant differences in the perception of foot temperature and humidity were found between the two kinds of footwear. Differences in thermal comfort perception by foot zones were also observed.

REVIEW AND THEORY

Comfort and functionality are features increasingly demanded by consumers. Footwear comfort is the result of a complex interaction of several factors that affect the foot function during human activity. These factors could be divided into mechanical and thermal aspects. Thermal comfort is defined by microclimatic characteristics of footwear, which are decisive factors for global comfort, even shortly after wearing the footwear (Kurz, 1992). Mechanical aspects have been widely studied and different techniques have been used to study subjective footwear comfort. Thermal factors have also been studied: temperature and humidity on diverse foot and body zones have been measured during experiments with subjects (Kurz, 1992 and Kawabata, 1993) and several laboratory tests have been developed. However, literature about subjective evaluation of thermal perception in footwear is scarce and it is limited to the evaluation of final comfort (Kawabata, 1993). In this context, design criteria for footwear thermal comfort improvement should not be only based on physiological parameters. The study of comfort assessments over time by body zones could provide valuable information for product evaluation and design (Shackel, 1969). A preliminary study is presented in this paper in which subjective perception of thermal comfort for foot zones has been evaluated over time. The goal of the study was to determinate if differences between shoes in thermal perception can be detected both globally and by foot zones.

PROCEDURES

Seven healthy males participated in the study. Two kinds of footwear with different expected thermal response were selected for the experiment (A - casual boot; B - casual shoe). Footwear microclimate and subjective perception were registered during the test. Temperature and humidity were measured between the first and second toes and on the longitudinal arch. Skin temperature on the foot plant (3rd metatarsal head) and instep, mean skin temperature and tympanic temperature were also recorded (Kurz, 1992). Subjective perceptions were registered using a bipolar seven-point scale (Shackel, 1969). Subjects were asked during the test about body thermal perception, humidity and temperature perception on the foot as a whole or by zone, footwear thermal comfort and footwear general comfort. Tests were carried out on summer (Ambient temperature: 25.9±0.9ºC; humidity: 57.2±6.8%; wind speed lower than 0.1 m/s). The test was divided into three phases. After a 20 minutes rest on a chair (Phase I. Warming up) the participants performed a 20 minutes exercise walking on a treadmill at a constant speed (Phase II. Dynamic steady state). Finally, the participants rested on a chair 20 minutes (Phase III. Cooling) (Kurz, 1992). Repeated measures statistical analysis of variance was used to determine if there were differences between shoes for subjective and physiological parameters during the test. Polynomial contrast was used to assess the time-shoe interaction model.

RESULTS AND CONCLUSION

In general, physiological parameters showed significant dependence with time. Global (over time) significant differences between shoes A and B were only observed in the measure of toes humidity ($p=0.004$). Although global significant differences have not been found for other physiological parameters, shoes A and B presented time response differences in some measurements.

Time-dependency was also observed in the humidity perception parameters. However, on most zones temperature perceptions did not change over time. Differences ($p<0.05$) in the subjective temperature ($p=0.012$) and humidity ($p=0.017$) foot perceptions between shoes A and B were observed (Figure 1). The temperature perception on most zones also presented differences between shoes. Differences in humidity perception were significant on the toes, arch and plantar metatarsal areas. Time-shoe interaction was significant for some foot zones. However, humidity and temperature foot perceptions did not present different time tendencies between shoes (Figure 1). In all cases, shoe A presented worse values in subjective and physiological parameters than B as it was expected.

Different time tendencies were observed between some physiological and subjective parameters. For example, humidity foot perception decreased in the dynamic phase (Figure 1), while humidity measurements in toes and arch increased considerably in this phase.

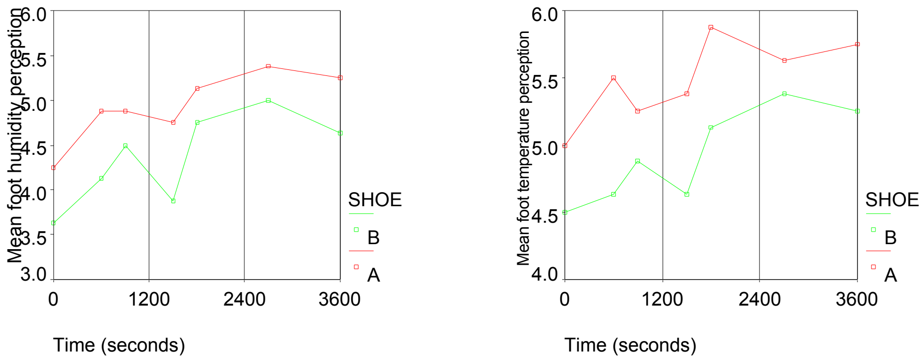

Figure 1. Estimated marginal means for general foot humidity (left) and temperature (right) perceptions (1. Very dry/cold; 4. Neutral; 7. Very damp/hot).

Subjects were capable to perceive thermal differences between shoes in diverse zones over time. Discrepancies have been found in time behaviour between objective and subjective parameters. These results justify the use of a subjective test over time for footwear thermal comfort evaluation as an asset for the physiological measurements. Further analysis in different ambient conditions with diverse footwear should be made in order to determine the relationship between physiological and subjective measures over time.

REFERENCES

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Physiological and subjective evaluation of footwear thermal response over time. J. C. GonzA¡lez, E. AlcA¡ntara, A. Bataller, A. C. GarcÃa Instituto de BiomÃ¡nica de Valencia. Spain.Â Two different kinds of footwear were tested and physiological and subjective data was registered during the experiments on diverse foot zones over time. Significant differences in the perception of foot temperature and humidity were found between the two kinds of footwear.Â However, literature about subjective evaluation of thermal perception in footwear is scarce and it is limited to the evaluation of final comfort (Kawabata, 1993). In this context, design criteria for footwear thermal comfort improvement should not be only based on physiological parameters. 2.1. Measurement of Physiological Responses: Tests with Wear Trials. As the wear comfort is directly related to physiological processes, it is possible to measure it quantitatively.Â The physiological reactions of wear trials can objectively be measured as a change of physiological parameters or perceived subjectively, based on the assessment of thermal comfort using subjective judgement scales.Â well as subjective evaluations of thermal comfort. Figure 4 shows the results of mean skin temperature changes of test persons, which wear different clothing systems in climate chamber at an ambient temperature of 25Â°C and on Figure 5 at an ambient temperature of 20Â°C. (a) Clothing systems cs1 and cs5. Subjective assessments showed relatively higher thermal sensation and pleasantness under indirect airflow. The psychological time calculated from counting behaviors was longer under indirect airflow, indicating suppression of negative emotions. The face temperatures significantly declined during experiments under direct airflow.Â Electroencephalography (EEG) is a strong candidate for the objective evaluation of airflow comfort. Some components of EEG signals are known to reflect mental states directly [15,16].Â The relationship between the subjective evaluation and physiological indicators, especially EEG, is also investigated. The physiological responses were measured under two airflow directions: direct and indirect cool air to the face. However, thermo-physiological and subjective sensations during the intermittent high-intensity exercise were similar for both fabrics.Â For subjective thermal measurements, each participant gave a verbal evaluation of their thermal condition using nine points rating thermal sensation (TSV, 4: very hot, 3: hot, 2: warm, 1: slightly warm, 0: neither, -1: slightly cool, -2: cool, -3: cold, and -4: very cold), seven points of thermal comfort (TCV, 3: very comfortable, 2: comfortable, 1: slightly comfortable, 0: neither, -1Â The more widely moisture is distributed over the skin, the stronger the discomfort sensation [12, 13]. For purposes of describing physiological responses to heat and cold, the body is divided into two componentsâ€"the â€œcoreâ€ and the â€œshellâ€. Core temperature (Tc) represents internal or deep body temperature, and can be measured orally, rectally or, in laboratory settings, in the oesophagus or on the tympanic membrane (eardrum). The temperature of the shell is represented by mean skin temperature (Tsk). The average temperature of the body (Tb) at any time is a weighted balance between these temperatures, that is. Tb = k Tc + (1â€" k) Tsk.Â When confronted with challenges to thermal neutrality (heat or cold stresses), the body strives to control Tc through physiological adjustments, and Tc provides the major feedback to the brain to coordinate this control.