STUDY OF COMFORT ASSOCIATED WITH TENNIS FOOTWEAR

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INTRODUCTION: The current methodology used in comfort studies appeared at the end of the 60s in ergonomics (Shackel et al., 1969). However, and despite its importance, there are very few works about comfort related to footwear in general, and less fewer related to technical sports footwear (Nigg et al. 1986).
Such methodology was applied in the present work for the purpose of analyzing the general (global) comfort, errors in footwear design perceived subjectively (subjective opinion) and the discomfort to parts of the body. Besides, we also aimed at analyzing the relative effect of the discomfort in body parts and the errors in design on global comfort, and at determining the effect of the design elements on the discomfort in different parts of the body.

MATERIALS AND METHODS: Following Shackel et al. (1969), data were collected in 5 tennis clubs of Valencia, by means of personal interviews administered in tennis courts immediately after tennis practice. Information was also collected on personal data (age, weight, gender, hours of practice, etc.) and footwear characteristics, both descriptive (height of top, type of fastening, heel-counters, etc.) and measured with portable instrumentation. The instrumentation served to measure the longitudinal (torsion) and transversal? (flexion) flexibility, the footwear-surface hold and the hardness according to the Shore A scale.
200 questionnaires were administered, so the maximum sampling error was *a priori* about 7% (estimated sample size of 4,000 tennis players).
The data were entered in an ACCESS data base to be later treated using SPSS and Statgraphics-plus statistical software. Besides the descriptive analysis of the different variables, cross-tabulation techniques and Chi^2, ANOVA, factorial analysis and correlation analysis (Pearson) were used.

RESULTS:
Characteristics of footwear: The existence of a hollow in the midsole at the midfoot level diminished longitudinal flexibility (torsion) of footwear samples ($p<0.05$ for the ANOVA). The mean values were 24.5º for the footwear samples without a hollow and 21.6º for the samples with a hollow. In the case of transversal flexibility, the result was near statistical significance ($p=0.062$ for the ANOVA).
Comfort: After analyzing the relationships between general comfort provided by the footwear samples and the discomfort in parts of the body and the errors in design (subjective opinions) perceived by the tennis players, the relationships found were as shown in Tables 1 and 2.

Table 1. Results ordered according to frequency of appearance of discomfort.

Anatomical area	Frequency (% of appearance)	Importance (Somers's D)	p
Midfoot plant	11.1	54.7	0.00001
Heel	9.0	23.3	0.00873
Achilles tendon	7.6	43.4	0.00317
First metatarsian internal side	7.6	33.6	0.02252
Fifth metatarsian external side	6.3	48.1	0.00286

Table 2. Results ordered according to frequency of error.

Design error	Frequency (% of appearance)	Importance (Somers's D)	p
Soft point	36.6	19.3	0.01937
Hard midsole	25.2	26.4	0.00647
Poor hold	22.2	22.4	0.02108
Soft midsole	21.9	20.4	0.04484
Rigid point	10.5	36.5	0.01441
Low rear midsole	10.0	31.6	0.02150

Regarding discomfort in body areas, 4 factors were defined which contain 64.7% of the original information, while 6 factors were defined for errors in design which contain 62.8% of the original information. These factors appear in Tables 3 and 4.

Table 3. Independent factors for discomfort in body areas.

Factor and code	Description (type of discomfort grouped)
Shock absorbency (M1)	Discomfort in heel, lumbar spine and, to a lesser extent, heel plant, internal side of first metatarsian and midfoot plant
Plantar pressure distribution (M2)	Metatarsal heads, midfoot plant and internal side of the first metatarsian
Functional adequacy of footwear to foot (M3)	Ankle and rear leg
Footwear rigidity (M4)	Dorsal flexion area of the toes and dorsal spine

Table 4. Independent factors for errors in design.

Factor and code	Description (type of errors grouped)
Too high (E1)	Too much height in the midsole
Hard and poorly flexible (E2)	Too hard point, poor flexibility, too hard midsole
Incorrect arch support (E3)	Too high or badly placed arch support
Incorrect last (E4)	Too long footwear, loose footwear (incorrect fastening or lacing), too hard back
Too wide back (E5)	Too wide back
Cross training (E6)	Too much hold to surface, too high top

After correlating both groups of factors, we obtained the following statistically significant associations:

- Factor E1 (too high) correlated with factors M1 (shock absorbency) ($r = -0.2492$ and $p = 0.003$), with M3 (functional adequacy of footwear to foot) ($r = 0.1861$ and $p = 0.023$) and with M4 ($r = 0.1548$ and $p = 0.049$).
- Factor E2 (hard and poorly flexible) correlated with M4 ($r = -0.2337$ and $p = 0.006$).

- Factor E3 (incorrect arch support) correlated with factor M2 (plantar pressure distribution) (r = 0.1866 and p = 0.022).

Comfort and elements of footwear design: From all the elements of design analyzed, the rearfoot heel-counters, the type of upper material and the midsole hollow at midfoot level were the elements of design which presented associations to discomfort (Tables 5, 6 and 7):

Table 5. Rearfoot heel-counter.

Anatomical area	Frequency (%)	Importance (%)	p
First metatarsal head	16.8	-19.8	0.01739
Toe plant	14.7	-17.4	0.02801
Heel plant	14.7	-17.4	0.02801
Midfoot plant	11.2	-16.5	0.01863
Front thigh	6.3	-12.5	0.02180

Table 6. Synthetic upper material.

Anatomical area	Frequency (%)	Importance (%)	p
Toe flexion area	10	13.2	0.02632
Heel	9.2	16.1	0.01634

Table 7. Midsole hollow at the midfoot level.

Anatomical area	Frequency (%)	Importance (%)	p
First metatarsal head	16.5	14.8	0.03924

DISCUSSION: Some of the errors in design and part of the discomfort in body areas are the direct cause of the tennis players' perception of the footwear as uncomfortable (Tables 1 and 2). However, the frequency with which this discomfort appears is between 6%-35% and the importance between 19%-55%, which explains the low percentage of tennis players who regard their footwear as uncomfortable.

From the correlations detected among the factors of discomfort in body areas and the errors in design, we must highlight:

- E1 and M1; the excessive height of the midsole is associated with the diminishing of discomfort attributable to shock absorption problems, possibly due to the increase of material between the surface and the foot.
- E1 and M3; the increase of discomfort in the ankle and rear leg possibly relates to the decrease of lateral stability.
- E2 and M4; footwear with too hard point, poorly flexible, and with too hard midsole diminish discomfort in the toe dorsal flexion area, possibly because the poor flexibility of such footwear prevents this area from suffering abrasion.
- E3 and M2; an incorrect (in location and height) arch support increases discomfort attributable to incorrect plantar pressure transmission-distribution during locomotion.

The results obtained with the flexibility machines show that the footwear provided with a midsole hollow at the midfoot level present a lower torsion level than the footwear without one. Besides, the footwear provided with a hollow presented a significant association with discomfort in the first metatarsal head area. Both results support the hypothesis that such a hollow has a mainly aesthetic role and not a theoretically functional purpose.

The inclusion of internal stabilizing heel-counters in the footwear rear diminishes the appearance of discomfort in different body areas, specially in the foot plant. This diminishing of discomfort could be due to the effect of the heel-counters on the rearfoot movement and the improvement of the shock absorbing properties of the heel pad soft tissue. Consequently, to the beneficial effect of the heel-counter on sports epidemiology can be added its positive effect on comfort.

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