INFLUENCE OF MIDSOLE CONSTRUCTION AND UPPER VAMP DESIGN ON THE PRONATION MOVEMENT WHILE RUNNING

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INTRODUCTION

The relationship between excessive pronation and some injuries in running has been widely described in literature (Cavanagh, 1990). Recently, Hamill and coworkers (1992) have suggested that a disruption in timing between the subtalar and knee joints might be also a mechanism of knee injuries. The influence of midsole design. and material in the amount of pronation has been analyzed by different authors. Nevertheless the relative influence of midsole and upper vamp design both on the amount of pronation and the timing disruption between pronation and knee flexion have not been studied enough. The objective of this work is to study the pronation movement while running and their relationship with shoes characteristics as midsole material and thickness and upper vamp design.

METHODOLOGY

In previous work it was analyzed the influence of several features placed in the upper vamp on controlling pronation (Ferrandis, Garc_a, Ramiro, Hoyos, & Vera, 1994). These features included lace anchors from eyelet to midsole, external heel counters and external heel counters with a post in the internal rearshoe. Between these elements, the heel counter and post showed to be the most effective feature to control pronation. Besides, a previous study of rigidity and loss tangent (energy absorbing capacity) of a group of PU materials was performed (Ferrandis, Garc_a, Durß, Ramiro, & Vera, 1993). From this study, three materials were selected because, of their marked differences in these mechanical parameters (Table 1)

	Rigidity (KN/m)		Loss tangent	
PU	1.5 cm	2.5 cm	1.5 cm	2.5 cm
I	230 E4 (4E4)	116 E4 (4E4)	0.129(0.004)	0.138(0.004)
2	277 E4 (4E4)	148 E4 (4E4)	0.228(0.004)	0.267 (0.004)
3	217 E4 (4E4)	107 E4 (4E4)	0.106(0.004)	0.165(0.004)

Table I: Mechanical characteristics . rigidity and loss tangent, of the three PU materials.

Twelve prototypes of running shoes were specially designed and manufactured. These prototypes corresponded to a factorial design of experiments with the following factors and levels: midsole thickness (15 and 25 mm), midsole material (3 types of PU) and inclusion or not of a external heel counter and post.

Three subjects participated in the study. All were pronators and heel-toe runners. A 3D kinematic study of the subjects while running wearing the prototypes was performed. The right lower leg was filmed with two cameras at 150 frames per second. The protocol used was as follows: each subject was asked to participate in a I-hr testing session. Both subjects and running shoes were marked following a model similar to that proposed by Soutas-Little (1987). Markers were located as follows: 1, at the greater trochanter of the femur; 2, at the lateral condyle of the femur; 3, at the head of the fibula; 4, at the lateral malleolus; 5, at the center of the heel cap at the insertion of the Achilles tendon; 6, at the center of the heel cap just above the shoe sole; 7, at the lateral side just above the shoe sole.

		Prototypes											
		1	2	3	4	5	6	7	8	9	10	11	12
Midsole Height	25 mm	X	X	X	X	X	X						
	15 mm							X	X	X	X	X	X
Heel Counter	With				X	X	X				X	X	X
	Without	X	X	X				X	X	X			
Type of PU	1	X			X			X			X		
	2		X			X			X			X	
	3			X			X			X			X

Table 2: Prototypes description.

First, the subject was given time to warm up, after this period subjects performed 5 series of run while randomly wearing a pair of the 12 prototypes. A 2 min. rest was allowed between series and used for the change of running shoes. Running speed was fixed at 4 m/s.

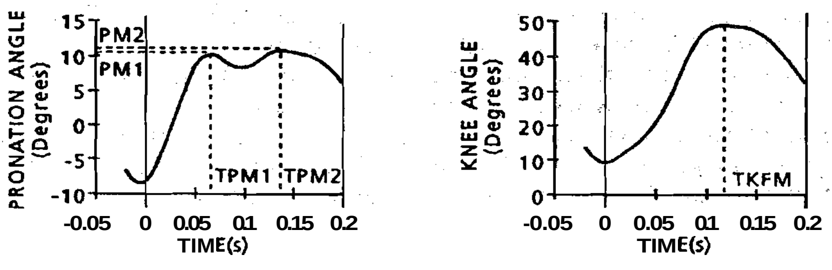

Figure 1: Pronation and knee flexion curves. Parameters selected for statistics.

All the frames of three right footfalls were manually digitized and data were processed to obtain the 3D coordinates of each marker using the DLT. A typical sequence was digitized 3 times for each digitizer in order to obtain the variance of noise of each coordinate of each marker. From these values the 3D coordinates were smoothed with quintic splines using the method of True Predicted Mean Square Error. For computing the pronation angles the FEA method (Areblad, Nigg, Ekstrand, Olsson, & Ekström, 1990) was used. Knee joint was considered to have only 1 degree of freedom. In figure 1 typical pronation and knee flexion curves are presented. From these curves a number of parameters were selected for the statistical analysis. These parameters are: PM1 (first maximum of pronation), PM2 (second maximum of pronation), TPM1 (time of first maximum of pronation), TPM2 (time of second maximum of pronation), TKFM (time of maximum knee flexion). With these parameters, PMAX (maximum pronation), TPMAX (time of maximum pronation) and TPMAX-TKFM (time disruption between subtalar and knee joints) were computed.

With these parameters, a multifactor analysis of variance (ANOVA) was performed considering as factors: subject, midsole thickness, midsole material and inclusion of the heel counter and post. Eor post hoc analysis the LSD method was used. Alpha level was fixed to 0.05.

RESULTS

Significant differences between subjects were found for all the variables studied.

		PM1 [°]	TPM1 [ms]	PM2 [°]	TPM2 [ms]	PMAX [°]	TPMAX-TKFM
MIDSOLE	25 mm	8.4 (0.4) (*)	54.2 (1.6)	9.8 (0.3) (*)	131.6 (2.5)	10.2 (0.3) (*)	5.1 (5.5)
TICKNESS	15 mm	6.4 (0.4)	52.2 (1.9)	8.8 (0.4)	132.2 (2.3)	9.2 (0.4)	20.8 (5.3) (*)
MIDSOLE	1	9.1 (0.5) (*)	56.9 (1.9)	10.4 (0.5) (*)	132.4 (2.4)	10.9 (0.5) (*)	7.8 (7.1)
MATERIAL	2	6.3 (0.4)	48.3 (2.3) (*)	8.6 (0.4)	132.1 (2.8)	8.8 (0.4)	12.1 (7.1)
	3	6.7 (0.5)	54.4 (2.0)	8.8 (0.4)	131.2 (3.5)	9.0 (0.4)	18.9 (5.8)
HEEL COUNTER	WITH OUT	7.6 (0.5)	54.3 (1.8)	10.1 (0.4)	135.8 (2.1)	10.4 (0.4)	22.2 (4.8)
AND POST	WITH	7.1 (0.3)	52.1 (1.7)	8.5 (0.3) (*)	128.1 (2.5) (*)	8.9 (0.3) (*)	3.6 (5.8) (*)

Table 3: Results for each level of the factors studied. (*) $P<0.05$.

Midsole thickness was found to affect to PM1, PM2 and PMAX. Higher angles of pronation were found for thicker midsoles. Nevertheless, times of occurrence of these maximum were not significativelly affected by the midsole thickness. Time disruption was increased by the low midsoles comparing with the thicker ones.

Significant influence of the midsole material on maximum pronation angles was found. Significant higher angles of PM1, PM2 and PMAX were found for the material 1 (the softest and most elastic one). Besides significant lower times of first maximum of initial pronation were found for material 2 (the most rigid and energy absorbing one). No significant effect in time of second maximum (TPM2) or time disruption between knee and subtalar joints (TPMAX-TKFM) with materials were found.

Referring to the upper vamp elements studied, the inclusion of the external heel counter and post showed to significatively reduce the second maximum of pronation (PM2) and the maximum pronation (PMAX). Besides lower disruption times (TPMAX-TKFM) were found for the prototypes including the external heel counter and post.

DISCUSSION AND CONCLUSIONS

Material and design of midsole has shown to have influenced both during the first and the final part of the pronation movement while running. Nevertheless the upper vamp elements studied showed only influence in the final part of pronation.

The heel counter and post was founded to reduce both maximum pronation and the timing disruption between pronation and knee flexion. This supports the idea of paying attention to the possibilities of the upper vamp in the control of pronation. Nevertheless midsole thickness has opposite effects because a thick midsole increases pronation while a low one increases the timing disruption between pronation and knee flexion. A careful design of **midsole** thickness is needed to balance these effects. A rigid and shock absorbing material showed lower angles of pronation without affecting the disruption time between pronation and knee flexion. The dominant trend of running shoes with very soft **midsoles** might be reconsidered from these results. Softer materials not only increase pronation but also is not demonstrated that reduce impacts. A thick and soft **midsole** without upper vamp elements for controlling pronation has been found to be the condition that leads to higher pronation.

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