GENERATION AND TRANSMISSION OF HEEL STRIKE IMPACTS IN CHILDREN RUNNING, FOOTWEAR AND GENDER INFLUENCE.

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INTRODUCTION

Heel strike impacts have been correlated with the development of degenerative joint diseases, as well as stress fractures and low back pain, (Wosk, 1986, Robbins, 1991). The human body possesses a number of active as well as passive natural mechanisms to attenuate these impacts. Shock absorption may be increased either by potentiating the natural shock absorbing mechanisms (eg heel pad confinement) or by adding external shock absorbing materials, like viscoelastic inserts (Forner, 1995). These findings have been obtained from and applied to adults. As a result, a new trend in sport footwear design including shock absorbing systems has centered the attention of the main sport footwear manufacturers (Fredericks, 1993). Nevertheless, there is a general lack of studies on impact absorption regarding children's footwear. Children aged 7-14 years present a high level of physical activity, however, their skeletal and neuromuscular systems are not yet consolidated. On the other hand, the negative effects of the impacts observed in adults may not be present in children, and osteogenic and stimulating effects of impacts must not be neglected. In spite of the fact that little information is available on the effects of heel strike impacts in children in this age range, children's sport footwear is in most cases designed according to criteria obtained from research in adults. It is widely accepted that children's sport footwear must provide at least as much shock absorption as in adults (Fredericks, 1993). Therefore, the study of heel strike impacts in childhood locomotion seems to be a very important factor in children's sport footwear design in order to avoid problems in child growth. This paper presents a pilot study to better understanding shock absorption and transmission in children. The presence of peaks in GRF and tibial acceleration when running is analysed, and the influence of factors such as gender, footwear and footwear type in shock absorption and transmission is studied.

METHODS

Eight healthy children (4 girls and 4 boys) aged 7-14 years were selected.

	BOYS		GIRLS		GLOBAL	
	Age	Weight	Age	Weight	Age	Weight
Running	9,87 (7.33-12.58)	41,7 (26.8-53)	11,16 (8.5-14.16)	46,45 (28-75)	10,51 (7.33-14.16)	44,07 (26.8-75)

Table 1. Subject description.

The parents were informed about the tests, and their consent was obtained. Each child was asked to run at free speed across a ten metres walkway stepping with the right foot on a force plate. The ground reaction force, measured by means of a force plate (Dinascan), and the acceleration on the tibia, measured by means of an accelerometer placed on the rigth lower limb, were recorded simultaneously. The accelerometer and its support, forming an assembly of less than 2.5 grs, were attached to the skin by double side adhesive tape. An elastic bandage wrapped tightly around the shank was used to fasten the accelerometer and to preload the skin, as described by Forner (1995). The accelerometer was wired to telemetry equipment in a rucksack. Each subject performed 5 valid trials under the following conditions in a random sequence: Two types of casual footwear, two types of sport footwear and barefoot. In order to ensure that the children performed heel-toe running, every trial was filmed and analyzed. The signals from both the force plate and accelerometer were stored, and maximum vertical impact force (Fzi), rate of load at impact (RFzi), maximum acceleration on tibia (Atib), rate of acceleration on tibia (Ratib) and shock wave transmission as the ratio of maximum acceleration of tibia with respect to maximum vertical force (SF=Atib/Fzi) were computed. A multifactor analysis of variance (ANOVA) was done with all these parameters, considering gender and test condition as factors. Age was considered as a covariate. The levels of configuration were chosen to analyze unshod vs. shod and casual vs. sport footwear.

RESULTS

The values of the parameters observed at heel-strike in vertical GRF and in tibial acceleration for boys and girls, both shod and unshod, are shown in the following table.

	Boys			Girls		
	Sport	Casual	Unshod	Sport	Casual	Unshod
fzi	1.49 ± 0.06 (**)	1.28 ± 0.06	1.44 ± 0.01	1.59 ± 0.1 (**)	1.23 ± 0.05	1.91 ± 0.01
Atib	3.38 ± 0.14 (*,**)	2.65 ± 0.16 (*)	4.32 ± 0.42	4.36 ± 0.27 (**)	3.87 ± 0.3	6.52 ± 0.37
Sf	2.45 ± 0.16 (*)	2.26 ± 0.16 (*)	3.04 ± 0.22	3.06 ± 0.2	3.27 ± 0.24	3.41 ± 0.11
Rfzi	41.69 ± 2.01 (*)	43.45 ± 2.41 (*)	85.33 ± 12.62	56.91 ± 3.46	49.99 ± 4.33	196.62 ± 22.07
Ratib	121.39 ± 7.77 (*)	110.73 ± 9.09 (*)	256.56 ± 46.99	172.29 ± 14.54	163.25 ± 18.67	424.88 ± 37.72

Table 2. Results for running tests: Boys and Girls; unshod, casual and sport footwear. (* significant difference between boys and girls, ** significant difference between sport and casual footwear).

Statistically significant differences were found between boys and girls in running. Shock transmission and tibial acceleration were higher in the girls. There were statistically significant differences for all the study parameters between shod and unshod conditions. Tibial peak acceleration and shock transmission were found to be higher barefoot, as has been observed in adults. The type of footwear used influenced shock absorption and transmission. Casual footwear gave rise to lower impact forces, tibial peak acceleration and RFzi than sport footwear. Sport footwear presented impact forces not different from those for barefoot condition.

Some works on children running present results where a heel strike can be observed in the vertical GRF curve (Engsberg, 1993) however, in the discussion of the results they do not take this loading into account. In this sense, peaks were seen to occur in tibial acceleration, the signal being similar to that registered in adults (Wosk, 1981, Forner, 1995). In the present work, it has been shown that impact forces do occur in children running, and that they do give rise to transient stress waves travelling through the body, as reflected by the tibial acceleration signal. When considered from adult footwear design criteria, the above results would support that protective footwear for children should be recommended. However, a detailed understanding of the effects of impact on the child body is needed before establishing footwear design criteria. Musculoskeletal, control and neuromotor systems are developing to an adult stage. Impacts have been shown to play an important role in bone growth (Jankovic, 1972). A similar role may be postulated concerning the neuromotor and control systems, and thus a too high absorption would attenuate the stimuli needed for growth and development. On the other hand, a child's skeleton is more compliant than an adult's, and so impact forces may be thought to have worse effects in children. However, at the same time the fat and cartilage content in children is greater, and thus their shock absorption capability could be expected to be greater. In contrast to this, Kinoshita (1993) measured a lower shock absorption in children heel pad than in adults. Kinoshita used a drop test with only two children, which was a limited sample. In this sense, the shock absorbing properties of natural mechanisms should be assessed in children. Robbins (1991) proposed a feedback model for impact attenuation behaviour, where the subject adapts to impact conditions, attenuating them by means of changes in movement (increasing knee flexion, etc.) in such a way that, if impact perception is altered, the subject will not adapt to the impact, increasing shock transmission. According to this model, impact perception in children will follow a maturation process, and impact adaptation will depend on child age. Girls present higher forces and acceleration in running. This can be explained by the fact that girls grow and mature faster than boys; their skeleton is thus more consolidated and can withstand greater forces, and their movement pattern is more developed. It has to be considered that the sample used in this study is small, and a larger study should be undertaken in order to generalize the results in gender influence. In any case, the results here presented clearly show that gender is a factor to be considered when studying children locomotion, and that footwear should be designed taking into consideration its influence. Surprisingly, sport footwear resulted in greater impact forces and tibial acceleration in running than casual footwear.

Sport footwear is normally regarded as more shock absorbing than casual footwear, and the results obtained could be explained either as a consequence of sport footwear badly designed, or due to a bad perception of impact with the sport footwear, according to Robbins (1991). Then, children's sport footwear should be specially designed from children characteristics.

CONCLUSION

The results of this work show that heel-strike in children running produces impact forces which give rise to a transient stress wave travelling through the body. Gender differences were found, as the girls show greater impact forces and accelerations, due to the earlier maturation stage. The type of footwear used influenced shock absorption and transmission. It seems that a compromise between shock absorption and impact perception should be considered in the design of children footwear. This preliminary study presents new results in children running. Nevertheless, further work is suggested to achieve a better understanding of shock absorption and transmission in children.

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