GROUND REACTION FORCES PRODUCED IN BASKETBALL MANEUVERS WITH NEW AND STRUCTURALLY DAMAGED SHOES

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The purpose of this study was to determine the difference in ground reaction forces between new shoes and shoes with obvious structural damage. Six male Division III basketball players performed eight directional basketball maneuvers in random order on an AMTI© 1000 force plate. Subjects were tested when the shoes were new and after the shoes had structural damage. Results indicated that forces were significantly higher in new shoes than damaged shoes (vertical: left forward, peak-1; left shuffle, peak-2; left back, peak-1 and ms; medial-lateral: left shuffle, peak-2; anterior-posterior: forward, peak-2; left back, peak-1; back, peak-1). No significance was found in time to peak forces or total time. This study concluded that new shoes showed significantly higher forces than shoes with obvious structural damage.

KEY WORDS: basketball, ground reaction forces, shoes

INTRODUCTION: Forces experienced during some basketball maneuvers in elite players are higher than those reported for elite gymnasts and runners (McClay, et al., 1994a). Cutting, landing and sprinting are movements that produce force in the lower extremities. Proper footwear may aid in the reduction of injuries by absorbing some force produced, however the effect of shoes on the kinematics of movement during basketball are inconclusive (McClay, et al., 1994a). A cushioned surface may aid in the absorbance of impact forces and reduce injury but an over-cushioned surface can also cause injury. An over-cushioned surface can cause instability which may lead to a lack of neutralization in the joint (Robbins & Waked, 1997). New shoes are meant to have proper balance between adequate shock absorption and stability.

Although research has indicated a need to replace running shoes every 300-500 miles, depending on the interaction between the person and the shoe (Wilk & Valdez, 2003a; Wilk & Valdez, 2003b), guidelines have not been established for basketball shoes. The purpose of this study was to determine the differences in ground reaction forces between new shoes and shoes that have obvious structural damage.

METHOD: This study was approved by the Institutional Review Board at the University of Puget Sound. Written informed consent was obtained prior to testing sessions. The subjects were 6 male collegiate Division III varsity basketball players. Height and weight (mean: 1.89 m and 85.97 kg) were recorded during the first testing. Force data was collected using an AMTI© 1000 force plate at 600 Hz.

Prior to testing, participants warmed up on a cycle ergometer for five minutes. Subjects performed eight different movements in random order on the force plate. The eight directional movements included: a forward sprint, a plant and backward movement, as well as right and left forward cutting, side shuffle, and back diagonal motions (Figure 1). Several recordings were taken to ensure an accurate representation of the average ground reaction forces experienced under each condition.

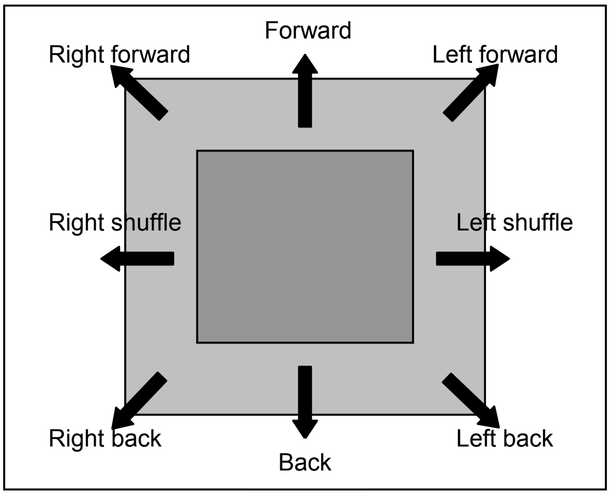

Figure 1. Force plate with eight movement directions

The subjects were tested when the shoes were new and after the shoes had structural damage. Structural damage was defined as when the soles of the shoes visually separated from the shoe or stitching had come undone. The ground reaction force data, vertical (V), anterior-posterior (AP), and medial-lateral (ML), collected for the eight movements over the two testing periods were evaluated using dependent t-tests ($\alpha < .05$) to indicate if significant differences occurred.

RESULTS: A significant increase occurred in time to vertical mid-stance in the left back maneuver for the damaged shoes, but all other time to peak forces were not significantly different. Total time of each maneuver showed no significant difference between new and damaged shoes (Table 1). The V mean peak-1 force (Table 1) was significantly greater in the new shoes for both the left forward and left back maneuvers. The mean V ms and peak-2 forces were greater in new shoes for both the left back and side shuffle, respectively.
The new shoes showed significantly higher mean peak forces in the ML direction (1.00 BW units) compared to the old shoes (.88 BW units) for the side shuffle (Table 2).
The AP mean peak-1 force was significantly higher in the new shoes (1.26 BW units) compared to the old shoes (1.07 BW units) for the back pedal. The AP mean peak-1 force (Table 3) also was significant in the left back motion (new=1.53 BW units and old=.61 BW units). In the forward sprint mean peak-2 force was greater in the new shoes (.58 BW units) than in the old shoes (.45 BW units).

Table 1. Mean (SD) in BW units of vertical ground reaction peak forces and total time (frame #)

	Peak-1 new	**Peak-1 old**	**Ms new**	**Ms old**	**Peak-2 new**	**Peak-2 old**	**Total time new**	**Total time old**
Movement	**Mean (± SD)**	**Mean (± SD)**	**Mean (± SD)**	**Mean (± SD)**	**Mean (± SD)**	**Mean (± SD)**	**Mean (± SD)**	**Mean (± SD)**
Forward	3.06 (± .22)	2.79 (± .45)						
Left forward	3.01 (± .18)*	2.67 (± .50)*					152.5 (±27.20)	146.5 (±11.76)
Left shuffle	2.04 (± .36)	2.02 (± .42)	1.8 (± .41)	1.91 (± .49)	1.98 (± .20)*	1.69 (± .20)*	245.17 (±15.14)	244.67 (±27.29)
Left back	2.17 (± .31)*	1.94 (± .33)*	1.53 (± .29)*	1.31 (± .27)*	1.85 (± .22)	1.63 (± .18)	303.17 (± 41.63)	301.17 (±57.46)
Back	1.78 (± .25)	1.61 (± .37)	1.26 (± .17)	1.25 (± .31)	1.75 (± .07)	1.63 (± .26)	306.67 (±38.88)	293.17 (±58.26)

*Significant at $\alpha < .05$

Table 2. Mean (SD) of medial-lateral ground reaction peak forces in BW units

Movement	**Peak-1 new Mean (± SD)**	**Peak-1 old Mean (± SD)**	**Ms new Mean (± SD)**	**Ms old Mean (± SD)**	**Peak-2 new Mean (± SD)**	**Peak-2 old Mean (± SD)**
Forward	.16 (± .095)	.13 (± .11)				
Left forward	1.14 (± .28)	.99 (± .24)				
Left shuffle	.54 (± .19)	.49 (± .13)	.32 (± .53)	.46 (± .11)	1.00 (±.13)*	.88 (± .20)*
Left back	.26 (± .07)	.26 (± .10)	.18 (± .11)	.19 (± .10)	.53 (± .08)	.50 (± .08)

*Significant at $\alpha < .05$

Table 3. Mean (SD) of anterior-posterior ground reaction peak forces in BW units

Movement	**Peak-1 new Mean (± SD)**	**Peak-1 old Mean (± SD)**	**Peak-2 new Mean (± SD)**	**Peak-2 old Mean (± SD)**
Forward	.32 (± .14)	.33 (± .16)	.58 (± .17)*	0.45 (± .17)*
Left forward	1.12 (± .33)	.84 (± .3)	.27 (± .13)	0.25 (± .09)
Left shuffle	1.22 (±.16)	1.13 (± .36)		
Left back	1.53 (± .30)*	.61 (± .35)*		
Back	1.26 (± .16)*	1.1 (± .34)*		

*Significant at $\alpha < .05$

DISCUSSION: This study indicated that mean forces were significantly greater in new shoes than in damaged shoes. As the shoes were worn, the cushioning may have compressed creating a harder mid-sole. Hardin, Van Den Bogert and Hamill (2004) found that with a harder surface or mid-sole the body altered impact forces by increasing flexion at lower leg joints. An increase in flexion can alleviate the force on the body. It has also been found that harder soles in shoes will decrease the vertical impact forces (De Wit, De Clercq, & Lenoir, 1995). Those findings agree with the results of this study. All significant differences in mean force from new to old shoes had larger forces in the new shoes. The forces produced were less than those previously reported in McClay et al. (1994a) for shuffling (2.6) and running (2.0-2.9) in basketball for the V forces but were higher in the AP force (.13-.5 for shuffling and .4 for running). This could be due to method differences between the two studies. McClay, Robinson, Andriacchi, et al. (1994b) tested subjects only once, while this study had a pre and post-test. The forward sprint in this study was a self-selected speed, while McClay et al. (1994b) had subjects run at a 7 min/mile pace. These variations could have caused the differences in force.

Another study found that as humans land on soft surfaces, they increase the vertical impact through a decrease in flexion of the lower extremities (Robbins & Waked, 1997). The subjects in this study did not land on a softer surface, but instead had footwear that provided the extra cushioning when the shoes were new. A newer shoe will have more cushioning and may cause a person to decrease flexion in the lower extremities to increase the force at which they land. An increase in force on a soft surface will help with stability (Robbins & Waked, 1997).

Time to peak forces were also recorded, but showed no significance except in the V mid-stance of the left back maneuver. Valiant and Cavanagh (1985) also found that there is only a moderate change in the average force-time curves within subjects. This indicated that even as the shoe became structurally damaged, performance was not compromised. Subjects are able to adjust their performance by minimizing force or making kinematic adjustments through adaptation mechanisms (Bates & Stergiou, 1996; Nigg, Bahlsen, Luethi, et al., 1987). Dufek and Bates (1991) concluded that there are individual differences in person-shoe interaction. This makes it difficult to standardize a time of adequate shoe replacement for the entire population.

CONCLUSION: No significant changes in time to peak forces were found but new shoes showed significantly higher ground reaction forces than shoes with obvious structural damage.

REFERENCES:

Bates, B.T. & Stergiou, N. (1996) Performance accommodation to midsole hardness during running. Journal of Human Movement Studies, 31(4), 188-210.

De Wit, B., De Clercq, D. & Lenoir, M. (1995) The effect of varying midsole hardness on impact forces and foot motion during foot contact in running. *Journal of Applied Biomechanics, 11*, 395-406.

Dufek, J.S. & Bates, B.T. (1991) Dynamic performance assessment of selected sport shoes on impact forces. *Medicine and Science in Sports and Exercise, (23)*9, 1062-1067.

Hardin, E.C., Van Den Bogert, A.J. & Hamil, J. (2004) Kinematic adaptations during running: Effects of footwear, surface and duration. *Medicine and Science in Sports and Exercise, 36*(5), 838-844.

McClay, I.S., Robinson, J.R., Andriacchi, T.P., Frederick, E.C., Gross, T., Martin, P., Valiant, G., Williams, K.R., & Cavanagh, P.R. (1994a) A profile of ground reaction forces in professional basketball. *Journal of Applied Biomechanics, 10*, 222-236.

McClay, I.S., Robinson, J.R., Andriacchi, T.P., Frederick, E.C., Gross, T., Martin, P., Valiant, G., Williams, K.R., & Cavanagh, P.R. (1994b) A kinematic profile of skills in professional basketball players. *Journal of Applied Biomechanics, 10*, 222-236.

Nigg, B.M., Bahlsen, H.A., Luethi, S.M. & Stokes, S. (1987) The influence of running velocity and midsole hardness on external impact forces in heel toe running. *Journal of Biomechanics, 20*, 951-960.

Robbins, S. & Waked, E. (1997) Balance and vertical impact in sports: Role of shoe sole materials. *Arch Phys Med Rehabil, 78*, 463-467.

Valiant, G.A. & Cavanagh, P.R. (1985) *Biomechanics IX-B*, Champaign, Ill., Human Kinetics, 117-122.

Wilk, B.R. & Valdes, M.M. (2003a) Running shoes wear out before they stop working. *Running & Fitnews, 21*(3), 5

Wilk, B.R. & Valdes, M.M. (2003b) Running shoes wear out before they stop working. *Running & Fitnews, 21(*4), 5

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