IMPULSE AND PROFILE OF GROUND REACTION FORCES IN BASKETBALL MANEUVERS IN NEW AND STRUCTURALLY DAMAGED SHOES

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The purpose of this study was to report typical ground reaction force curves and mean impulse in both new shoes and shoes with obvious structural damage. Ground reaction forces for eight maneuvers (forward, backward, as well as right and left cutting, side shuffling and diagonal backward motion) were recorded on two separate occasions. Typical force profiles were discussed as they differed between the new shoes and damaged shoes in each of the maneuvers. Mean total vertical impulse, subtracting out the product of body mass across total contact time, was significantly higher in cutting both forward and backward motions with the damaged shoes. Conversely mean vertical impulse was significantly lower in the side shuffle and reversal of direction for the damaged shoes. It was concluded that impulse and force curves change in shoes that are damaged through normal wear.

KEY WORDS: durability of shoes, basketball, impulse

INTRODUCTION: There is an abundance of research related to running shoes and the effects of midsole density, impact attenuation, and durability of the shoes (De Wit, De Clercq, Lenoir, 1995; Nigg, Morlock, 1987; Hardin, Van Den Bogert, Hamill, 2004). Typical force curves for running and jogging are well established in the literature and predominant in texts used to teach biomechanics (Hamill & Knutzen, 2004). In contrast, only a few studies have reported kinetic data associated with cutting, stopping and side shuffling that are predominant in basketball (McClay et al., 1994; Simpson et al., 1992; Neptune, Wright, Van Den Bogert,1999). McClay et al., provided typical force profiles that were representative of 24 professional basketball players who performed running, cutting, shuffling and stopping maneuvers. The mean peak force data and impulse in the vertical (V), medial/lateral (ML), and the anterior/posterior (AP) directions were reported, as well as the tracings of the typical curves. This data was essential in establishing a baseline understanding of expected profiles in ground reaction forces for basketball maneuvers (1994).
It is standard practice to replace running shoes every 300-500 miles, but there is little literature on replacement schedules and durability of basketball shoes. Most studies investigating cutting movements have focused on rearfoot kinematics, impact attenuation, or muscle coordination (Zhang et al., 2005; Simpson et al., 1992; Neptune, Wright, Van Den Bogert, 1999). The purpose of this study was to report typical ground reaction force curves and mean impulses in both new shoes and shoes with obvious structural damage.

METHOD: This study was approved by the University of Puget Sound Institutional Review Board. Experimental procedures were explained to six apparently healthy NCAA Division III college age male basketball players and consent was obtained to participate in the study. Mean height (1.89 m) and weight (85.97 kg) were recorded on the first visit to the exercise science lab prior to testing.
The subjects completed a 5 minute warm-up on a cycle ergometer set to light resistance. Data was collected on two separate occasions: once when the shoes were new (Trial 1) and once when the shoes had structural damage (Trial 2). The shoes were considered new if they had been worn to only one practice, while obvious structural damage was defined by the ripping of the stitched seams or separation of the sole of the shoe in the forefoot region. Participants performed eight selected movements as ground reaction forces were recorded using an AMTI© 1000 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. Vertical (V), anterior/posterior (AP), and medial/lateral (ML) forces were recorded over time and used to determine total impulse in Ns after subtracting out the product of body mass and contact time to complete the movement. Not all maneuvers warranted recording of impulses in the three planes of motion. Table 1 outlines the impulses calculated for each of the eight maneuvers. Dependent t-tests were used to determine significance in mean impulse between the new shoes and the shoes with obvious structural damage ($\alpha < .05$). Typical force curves for both trials were also reported for each of the movements.

RESULTS: For purposes of this study only left plant foot data were used, as uniform curves were evident in right/left cutting, side shuffle, and back cutting motions. Impulse was calculated as the area under the force time curve after body weight and contact time were subtracted (Table 1). Vertical impulses significantly increased from trial 1 (new shoes) to trial 2 (structural damage) for the forward and backward cutting. On the other hand vertical impulses significantly decreased in the side shuffle and reversal of direction. There were no significant differences in impulse in the anterior/posterior plane of motion. The medial/lateral impulse in the left cutting motion was significantly higher when the shoes had structural damage.
Typical curves for one subject are displayed for forward cutting, side shuffle, back cutting, as well as reversal of direction (Figures 2-5).

Table 1. Mean (SD) impulse in Newton seconds for new and structurally damaged (D) shoes

	Vertical		Anterior/Posterior		Medial/Lateral	
	Trial 1 New	Trial 2 D	Trial 1 New	Trial 2 D	Trial 1 New	Trial 2 D
Movement	Mean (± SD)	Mean (± SD)	Mean (± SD)	Mean (± SD)	Mean (± SD)	Mean (± SD)
Forward	100.11 (± 14.6)	82.27 (± 20.95)				
Forward cutting	131.50* (± 53.33)	185.06* (± 37.62)	114.93 (±38.19)	121.47 (±42.56)	49.19* (±29.65)	93.17* (±35.50)
Side shuffle	155.35* (± 42.22)	83.94* (± 44.12)			113.71 (±65.89)	124.56 (± 83.51)
Back cutting	100.56* (± 45.28)	164.84* (±50.19)	50.7 (±41.12)	110.12 (±46.87)	298.19 (±60.50)	282.67 (±73.23)
Reversal	143.65* (±16.50)	74.61* (± 41.65)	92.99 (±33.13)	112.11 (±72.45)		

*Significant at $\alpha < .05$

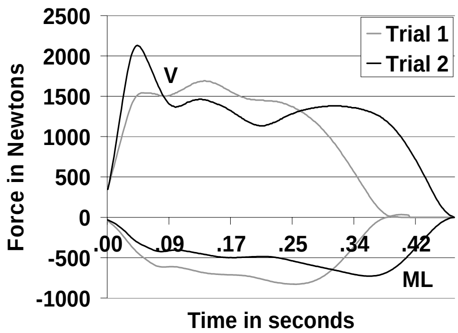

Figure 2. Typical side shuffle

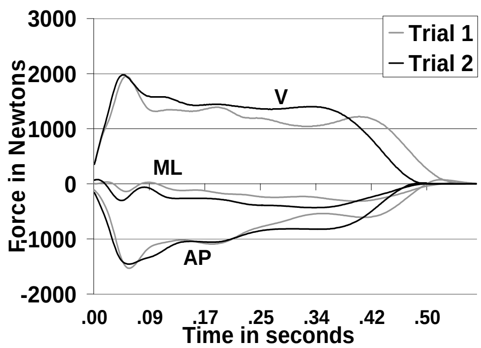

Figure 3. Typical forward cutting

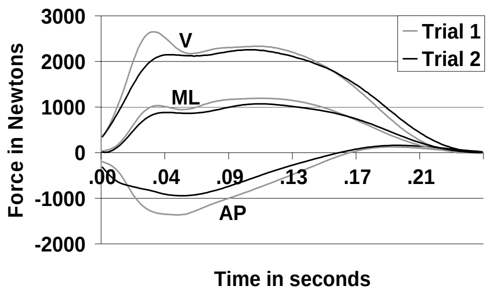

Figure 4. Typical reversal of direction

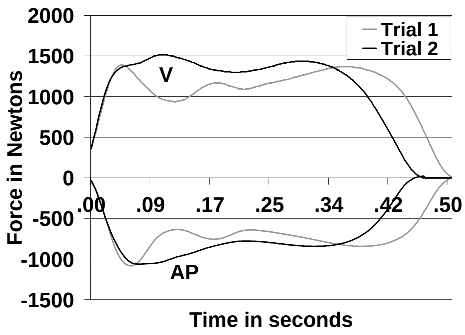

Figure 5. Typical back cutting

DISCUSSION: McClay et al., 1994b reported impulse for 24 professional basketball players in shoes without damage for a number of cutting maneuvers in the V, AP, and the ML planes of motion. Impulse numbers were comparable to the current study in forward running, forward cutting, and side shuffling. The other motions were unique to each of the studies and were not compared. The vertical impulses were significantly higher for the damaged shoes versus the new shoes in both the forward and backward cutting motions. In contrast the vertical impulses for side shuffling and reversal of direction were significantly more in the new shoes. Both the side shuffle and reversal of direction caused a heel plant in order to change directions, while the cutting motions were accomplished on the ball of the foot. This may explain why the cutting motions increased in vertical impulse while the heel plant motions decreased in vertical impulse. The body may compensate by un-weighting the damaged shoe in order for direction to be changed in the side shuffle and the reversal of motion The cutting motions on the ball of the foot would need to increase the mean impulse in order to compensate for the delayed response time of the shoe to the surface. When looking at individual subject's force curves the damaged shoe had lower peak forces, but increased total contact time. Even though total contact time was not significantly different from new to damaged shoes, individual curves showed a tendency to have lower peak forces over an increased total contact time.

The medial/lateral forces increased from new to damaged shoes in the forward cutting maneuver, but they were still well below those reported by McClay et al., (1994b). The damaged shoes in the cutting motion in the ML were 97.17 Ns, while values for professional players have been reported at 132.9 Ns. The skill level between the subjects in the two studies is quite apparent and most likely the explanation between the differences in the numbers. Differences between the subjects in McClay et al. study and the current study might also be attributed to the body weight. Although body weight was multiplied by the contact time and was than subtracted from the total area under the curve, forces are usually measured in body weight units, which would cause heavier athletes to have increased impulse. The subjects in this study were relatively light weight probably due to the intensity of practice, games and relatively younger age than those of other studies

It is important to notice that the variance of scores, as measured with standard deviation, were quite high for forward cutting and reversal in the AP, back cutting in the ML, and reversal in the V When looking through the individual force time curves there was a wide array of changes that occurred based on individual differences. In many studies the differing responses to the same conditions by subjects have caused mixed results (Bates, Stergiou, 1996; Hardin, Van Den Bogert, Hamill, 2004) and difficulty in finding group mean significant differences.

CONCLUSION: Mean vertical impulse increased in cutting motions with the damaged shoes, while new shoes showed increased mean impulses for the new shoes. Ground reaction curves do change with normal wear of basketball shoes.

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