THE EFFECT OF SHOE WEAR ON THE DROP STEP

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Peak jump height and the efficiency of the closed kinetic chain in basketball can contribute to the success of an individual player or team (Dowling, Vamos, 1993). This performance can be altered as shoe structure is compromised, possibly leading to a decrease in performance. The purpose of this study was to determine if angular velocity at the knee and hip as well as jump height performance were compromised with shoe deterioration. In this study, 12 male members of an NCAA Division III basketball team performed a drop step movement with a vertical jump. Subjects were filmed with a digital video camera filming at 60 Hz and vertical force (Fz) data was recorded using a force plate. Knee angles increased significantly ($\alpha < 0.05$) over the eight weeks of testing. Additionally, total time and peak height decreased while vertical force at toe-off increased. Although total time for performing the drop step movement was decreased throughout the study, peak jump height was compromised with shoe deterioration.

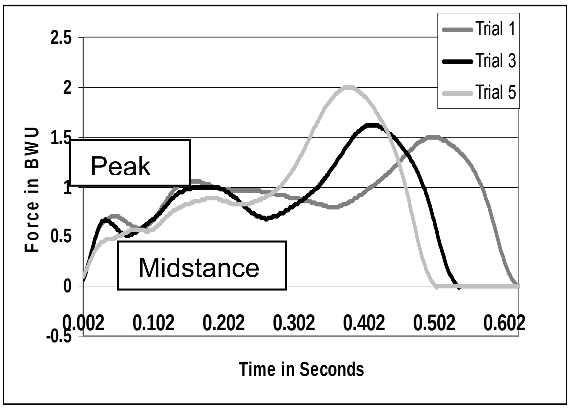
KEY WORDS: peak height, drop step, shoe deterioration

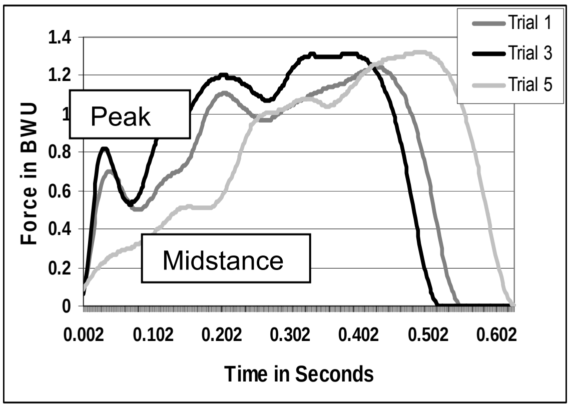
INTRODUCTION: A kinetic chain is defined as a series of sequentially activated segments that produce a coordinated movement. More specifically, a closed kinetic chain has both the proximal and distal ends fixed to either a stationary or moving object, restricting free movement, such as the double leg vertical jump in a basketball drop step maneuver (Ellenbecker, Davies, 2001). The distal end is fixed to the ground, whereas the proximal end is fixed to the trunk. Movement at one segment produces movement or affects motion at all other joints in the chain (Ellenbecker, Davies, 2001). In basketball, a closed kinetic chain is frequently used in vertical jumping, and may be a contributing factor of shoe breakdown. The efficiency of the closed kinetic chain may be compromised with varying compliancy in the shoe. If the hip, knee, and ankle joints need to fire in rapid succession it would be helpful for the body to have a consistent stiffness to react against in order to maximize the efficiency of the chain (Kreighbaum, Barthels, 1985). Although some research has been conducted in the area of shoe cushioning and support, limited research has been done regarding athletic shoe durability. The purpose of this study was to determine if angular velocity at the knee and hip as well as jump height performance in a basketball drop step were compromised with shoe deterioration.

METHOD: This study was approved by the University of Puget Sound Institutional Review Board. All procedures were explained and informed consent was obtained from nine apparently healthy male members of an NCAA Division III basketball team at the University of Puget Sound. Mean height (1.89m) and mass (85.74kg) of the subjects were recorded at the initial testing period. The amount of shoe wear was recorded daily throughout the study by counting average number of steps taken in the shoes per hour. Every two weeks for ten weeks, each subject was asked to perform a basketball drop step maneuver simulating an action common to the post player. The drop step started from a stationary position. The subjects turned 180 degrees to the right, planted the right foot on the force plate, loaded with both feet and performed a vertical jump with upward arm swing. Vertical force (Fz) was recorded throughout the drop step movement with an AMTI 1000 force plate (600 Hz). Three jumps were recorded during each testing period with the highest jump digitized for analysation.

All trials were filmed in the sagittal plane using a JVC 700x digital video camera filming at approximately 60 Hz (59.94 Hz). Filming occurred from the stationary position just before turning to just after toe off from the force plate. The field of motion was calibrated using a one meter stick in the vertical and horizontal planes. A spatial model of the body was developed to outline the movement at each joint during a drop step, and analyzed using SIMI°Motion Analysis v. 5.2 (Unterschleissheim, Germany). The angular velocities at the knee and hip were determined from the spatial models as well as peak height across the three trials. A repeated measures one-way analysis of variance (1 x 3) was used to determine significance ($\alpha < 0.05$) using trials 1 (new shoes), 3 (4 weeks), and 5 (8 weeks).

RESULTS: In this study, knee angles increased significantly ($\alpha \leq 0.05$) from new shoes to week eight. Total time for performance of the drop step and peak height reached approached significance ($p < 0.073$ and $p < 0.080$), each decreasing across the three testing periods. Hip angles increased across time; however, they did not approach significance. Additionally, kinetic data analysis indicated that vertical force increased significantly at toe-off with shoe deterioration. Knee and hip angular velocities were not significant. Although some subjects exhibited a cushioning curve (peak one and midstance) in the initial phase of the drop step maneuver (Figures 1 and 2), these forces or time to forces were not significant. For complete results, see Tables 1 and 2.





Figures 1 and 2: Vertical force graphs of two typical subjects.

Table 1. Mean and SD of kinematic data.

	12/4/2005 New	1/7/2006 4 Weeks	2/5/2006 8 Weeks
Knee angle (deg)	*103.6 (8.3)	*108.3 (8.0)	*110.3 (11.3)
Knee angular velocity (deg/s)	602.7 (75.0)	571.7 (67.9)	548.5 (116.5)
Hip angle (deg)	100.9 (14.6)	109.2 (15.1)	109.1 (16.9)
Hip angular velocity (deg/s)	426.4 (72.1)	431.3 (52.2)	456.5 (83.7)
Total time (s)	*0.575 (0.055)	0.546 (0.053)	*0.541 (0.046)
Peak height (m)	*0.589 (0.168)	0.525 (0.143)	*0.498 (0.089)

* significant $\alpha < 0.05$

Table 2: Mean and SD of kinetic data.

	12/4/2005 New	1/7/2006 4 Weeks	2/5/2006 8 Weeks
Fz Peak 1 (BW)	.475 (.186)	.541 (.208)	.451 (.111)
Fz Midstance (BW)	.430 (.176)	.502 (.232)	.442 (.117)
Fz Peak 3 (BW)	*1.306 (.351)	*1.471 (.279)	*1.515 (.273)
Time Peak 1 (s)	0.052 (0.029)	0.050 (0.017)	0.063 (0.043)
Time Midstance (s)	0.082 (0.032)	0.089 (0.029)	0.081 (0.048)
Time to Exceed Peak 1 (s)	0.098 (0.046)	0.106 (0.112)	0.086 (0.055)
Time Peak 3 (s)	0.4227 (0.083)	0.381 (0.085)	0.417 (0.046)

* significant $\alpha < 0.05$

DISCUSSION: As the cushioning decreased through shoe deterioration across the eight weeks of study, less total time was spent performing the drop step motion ($p < 0.073$). Although the motion was performed faster with shoe wear, overuse of broken shoes could potentially lead to injury. Jorgensen (1990) discussed that low levels of shock absorption in shoes (such as through deterioration) could lead to an increase in shock absorption by the muscles, leading to an increase of overuse injuries. Although total time decreased, peak height was compromised as the shoes deteriorated. This occurred even though peak vertical force values increased. This seems a bit inconsistent unless efficiency is compromised with shoe wear. It could be that as the shoe absorption decreases, the rapid succession of firing in the joints is mistimed slightly, causing peak jump height to decrease. Future studies might want to investigate this premise more closely.

With increased force at toe-off, less cushioning may have been available. In new shoes, the high impact forces are absorbed by the shoe cushioning, but as deterioration progresses and shock absorption decreases, the foot could have delivered more force downward during toe-off to generate enough energy to leave the ground in the vertical jump. Clarke, et al. (1983), however, found that softer shoes had a greater propulsive force at toe-off than hard shoes during running. It is possible that the difference between running propulsion and vertical jump toe-off may have different reactions to shoe cushioning. Dowling and Vamos (1993) noted that subjects had to generate forces more than twice their body weight (in addition to correct muscle coordination) in order to jump at least 30 cm. Additionally, high take-off velocity and high peak powers at each joint added to maximal jump height performance. Aragon-Vargas and Gross (1997) added that the vertical positioning of the center of mass was also a good indicator of peak jump height performance.

Increasing knee and hip angles with shoe deterioration may be due to less eccentric pre-stretching occurring before push off. Eccentric pre-stretching is a movement that maximizes jump height by creating a stronger concentric force upward. The stretch-reflex action is characterized by an eccentric pre-stretch of the quadriceps immediately prior to a strong concentric contraction (Santana, 2004). Potential energy is gained through the elasticity of the movement, resulting in a more explosive jump (Mackenzie, 1997). If the eccentric pre-stretch is compromised, seen in increasing angles at the knee and hip, then peak jump height can also be compromised. During shoe deterioration, the lower extremity muscles must compensate for the lack of shock attenuation in the shoe (Jorgensen, 1990). It is possible that this could lead to a reduction in eccentric pre-stretch effectiveness, and thus, a reduction in jump height performance.

Researchers disagree as to the contributions of each joint in the lower extremity to the vertical jump. The discrepancy in the evidence suggests that kinetic chain patterns vary between subjects and that compensation can occur (Ellenbecker, Davies, 2001; Hubley, Wells, 1983; Robertson, Fleming, 1987; Luhtanen, Komi, 1978). Additionally, subjects may wear out shoes differently, creating different compensation patterns in the closed kinetic chain. In this study, both hip and knee flexion decreased (Figure 3). Changing hip and knee angles could also be a result of compensation for shoe deterioration. Hardin, et al. (2004) attributed hip flexion decreases to compensation for cushioning deficiencies.

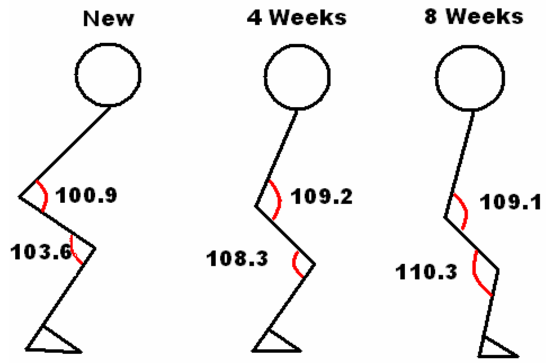


Figure 3: Progression of decreasing hip and knee angles across eight weeks of study.

CONCLUSION: Peak height appeared to be compromised with deterioration in the shoe. Angles at the knee and hip increased with shoe deterioration while a decrease in total time was observed

REFERENCES:

Aragon-Vargas, L.F. and Gross, M.M. (1997). Kinesiological factors in vertical jump performance: differences among individuals. Journal of Applied Biomechanics 13(1), 24-44.

Clarke, T.E., Fredrick, E.C., and Cooper, L.B. (1983). Effects of shoe cushioning upon ground reaction forces in running. International Journal of Sports Medicine 4(4), 247-251.

Dowling, J.J. and Vamos, L. (1993). Identification of kinetic and temporal factors related to vertical jump performance. Journal of Applied Biomechanics 9(1), 95-110.

Ellenbecker, T.S. and Davies G.J. (2001). Closed kinetic chain exercise: A comprehensive guide to multiple-joint exercises. Champaign, IL: Human Kinetics.

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

Hubley, C.L. and Wells, R.P. (1983). Work-energy approach to determine individual joint contributions to vertical jump performance. European Journal of Applied Physiology and Occupational Physiology 50(2), 247-254.

Jorgensen, U. (1990). Body load in heel-strike running: The effect of a firm heel counter. The American Journal of Sports Medicine 18(2), 177-181.

Kreighbaum, E. and Barthels, K.M. (1985). Biomechanics: A Qualitative Approach for Studying Human Movement. Minneapolis, MN: Burgess Publishing Company.

Luhtanen, P. and Komi, P.V. (1978). Segmental contribution to forces in vertical jump. European Journal of Applied Physiology and Occupational Physiology 38, 181-188.

Mackenzie, B. (1997). Sports Coach Plyometrics. Online: Oct. 11, 2005.

<http://www.brianmac.demon.co.uk/plymo.htm>.

Santana, J. (2004). Perform Better. Online: Oct. 11, 2005, <http://www.performbetter.com/catalog/matriarch/OnePiecePage.asp_Q_PageID_E_58_A_PageName_E_ArticlePlyometrics1>.

Robertson, D.G.E. and Fleming, P. (1987). Kinetics of standing broad and vertical jumping. Canadian Journal of Sport Sciences 12(1), 19-23.

Acknowledgements:

This study was funded by a University of Puget Sound Research Grant.