EFFECTS OF MIDSOLE THICKNESS ON SINGLE LEG DROP LANDING GROUND REACTION FORCE AND DYNAMIC STABILITY

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Dynamic instability and high loading rates are associated with athletic injuries. Research is conflicting regarding the effect of midsole cushioning on ground reaction force variables. This study aimed to investigate the effect of athletic footwear midsole thickness on vertical force and dynamic stability in single leg 0.25 m drop landings. Eleven male field sports players performed 5 dominant and 5 non-dominant leg drop landings onto a force plate. The landings were performed barefoot and wearing four shoes of differing midsole thicknesses. Significantly larger vertical forces and rates of loading were found in the barefoot and minimal conditions, compared to the thickest midsole. The only significant differences in stability measures were larger AP CoP amplitude in barefoot and minimal to oversized midsoles (non-dominant leg only). These findings suggests wearers should be aware of potential increased injury risk in minimalist shoes and consider thicker midsoles if, following a period of adjustment, technique changes cannot be achieved to dissipate these forces.

KEY WORDS: injury risk, footwear, cushioning, balance

INTRODUCTION: Athletic footwear can affect balance and ground reaction forces (GRF) during exercise (Robbins & Waked, 1997). Dynamic instability and high loading rates are associated with athletic injuries (Zadpoor & Nikooyan, 2010). Some research has suggested exercising barefoot or wearing minimalist footwear might reduce instability (Bowser et al., 2017; Wyon et al., 2013) and decrease peak vertical force and rate of loading on landing (Bowser et al., 2017). Conversely, other studies have reported lower peak vertical force and rate of loading in more cushioned shoes (Fu et al., 2013; Malisoux et al., 2017) or no difference between barefoot and shod double-leg landing peak vertical force (Yeow et al., 2011). The aim of this study was to investigate the effect of athletic footwear midsole thickness on vertical force and dynamic stability in single leg 0.25 m drop landings.

METHODS: Eleven male University level field sports players participated in this study (Mean ± SD age: 21.8 ± 1.8 years; 1.59 ± 0.05 m; 76.5 ± 14.2 kg; all UK shoe size 9). The study was approved by the University's Research Ethics committee. All participants were free from injuries at the time of testing and in the past 12 months, passed a health screen questionnaire and foot and ankle ability questionnaire (Martin et al., 2005). Participants attended the University's Sport and Exercise Science Laboratories on one occasion. Dominant leg was established using a 17-task limb dominance assessment and height (Horltain Ltd., Crymych, UK) and mass (Tanita Corp., Tokyo, Japan) were recorded. Participants watched a demonstration of the movement to be performed. They completed a standardised warm up and familiarisation, including four drop landings on each leg, wearing their own footwear.

For the experimental testing, the participants performed ten single leg drop landings in five conditions in a randomised order - barefoot and four shod, differentiated by midsole thickness. 1: minimal (12 mm); 2: moderate (21 mm); 3: thick (27 mm) and 4: oversized (32 mm). Drop landings were performed five times on each leg from a 0.25 m drop jump bench on to a force plate (Kistler 9281C, Kistler Instruments, Switzerland; 1000 Hz). Participants had a one minute rest between trials and five minute rest between footwear types. Participants all wore the same socks for all shod conditions.

Trials were excluded from analysis if the participant stepped forwards following landing or their non-landing leg touched the floor. The variables calculated (Microsoft Excel) for each trial were landing peak vertical force (N), rate of loading (peak vertical force divided by time taken; N/s) and maximum displacement of the Centre of Pressure (CoP) in the anteroposterior (AP) and mediolateral (ML) directions (AP CoP amplitude and ML CoP amplitude). Mean and SD values for the five trials for each footwear condition and each leg (dominant and non-dominant) were calculated. Inter-trial reliability was deemed acceptable (ICC > 0.7 and CV < 20% for all variables). A repeated measures ANOVA (SPSS version 22.0, SPSS inc, Chicago) analysed differences between the footwear conditions. Bonferroni pairwise comparisons were used to identify where the differences lay. The alpha level for a statistically significant effect/interaction was set at $p < 0.05$.

RESULTS: Mean and SD for all variables and indication of significant differences are presented in Table 1 and Table 2. **Non-dominant leg:** peak vertical force and rate of loading (Figure 1) were significantly greater in the barefoot than the thicker mid-soled shoes (B, C, D) and in the minimal shoe (A) than the oversized (D) shoe. AP CoP amplitude was significantly greater barefoot and in the minimal shoe (A) than the oversized (D) shoe. **Dominant leg:** peak vertical force was significantly greater in the barefoot than all shoes and in the minimal (A) than the oversized (D) shoe. Rate of loading was significantly greater in the barefoot compared to thick (C) and oversized (D) shoes. There were no significant differences in stability measures among minimal moderate and thick midsoles.

Table 1. Mean (SD) non-dominant leg GRF variables in barefoot (BF) and shod (A, B, C, D) conditions.

	Barefoot (BF)	Minimal (A)	Moderate (B)	Thick (C)	Oversized (D)	*p*	Post hoc
Peak vertical force (N)	2884 (547)	2726 (480)	2536 (453)	2552 (548)	2437 (506)	*< 0.05*	BF > B,C,D; A > D
Rate of loading (N/s)	51407 (13955)	44472 (14563)	41765 (12794)	41006 (11935)	39090 (11951)	*< 0.05*	BF > B,C,D; A > D
AP CoP amplitude (m)	0.091 (0.023)	0.086 (0.015)	0.080 (0.020)	0.079 (0.014)	0.077 (0.015)	*< 0.05*	BF > D; A > D
ML CoP amplitude (m)	0.040 (0.011)	0.040 (0.010)	0.044 (0.013)	0.042 (0.007)	0.043 (0.010)	*> 0.05*	-

Table 2. Mean (SD) dominant leg GRF variables in barefoot (BF) and shod (A, B, C, D) conditions.

	Barefoot (BF)	Minimal (A)	Moderate (B)	Thick (C)	Oversized (D)	*p*	Post hoc
Peak vertical force (N)	2904 (542)	2686 (465)	2589 (523)	2565 (489)	2485 (400)	*< 0.05*	BF > A,B,C,D; A >D
Rate of loading (N/s)	51789 (15610)	44881 (15445)	43594 (14867)	41745 (11873)	40320 (11922)	*< 0.05*	BF > C, D
AP CoP amplitude (m)	0.086 (0.015)	0.080 (0.022)	0.080 (0.017)	0.077 (0.016)	0.078 (0.019)	*> 0.05*	-
ML CoP amplitude (m)	0.041 (0.011)	0.038 (0.004)	0.041 (0.010)	0.040 (0.007)	0.037 (0.005)	*> 0.05*	-

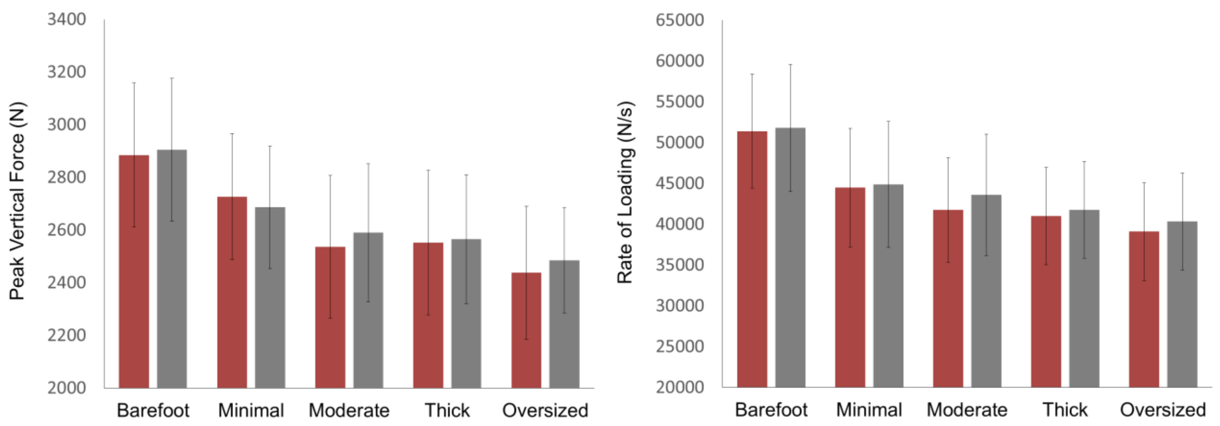

Figure 1. Non-dominant (red) and dominant leg (grey) in barefoot (BF) and shod conditions.

DISCUSSION: The aim of this study was to investigate the effect of athletic footwear midsole thickness on vertical force and dynamic stability in single leg 0.25 m drop landings. In general, there was a trend for larger forces and rates of loading in the barefoot and minimalist conditions, particularly compared to the oversized midsole, but very little difference between moderate and thick midsole thicknesses.

Peak vertical force was significantly larger in barefoot compared to all footwear (except minimal, non-dominant leg) and significantly larger in the minimal (A) compared to the most cushioned shoe (D), for both the dominant and non-dominant legs. Rate of loading was larger in the barefoot compared to the two more cushioned shoes (C and D) in both legs. This extends previous research finding reduced vertical forces with more cushioned footwear to 0.25 m drop landings (Fu et al., 2013; Malisoux et al., 2017). Bowser et al. (2017) reported lower peak vertical force and rate of loading in barefoot compared to standard footwear, evidence to support the use of minimalist footwear. The higher drop in the current study (0.25 m v 0.10 m) may explain the disparity with the Browser et al. (2017) study.

Overall, these results suggest that thicker midsoles provide more cushioning, decreasing vertical GRF and rate of loading compared to barefoot and minimalist footwear. Injury risk to the lower limbs may therefore be reduced.

However, the limited differences between moderate, thick and oversized footwear suggest that disparity between these footwear types should not be assumed. Further research integrating kinematics and kinetics is required to understand whether it is changes in technique during landing or absorption by the footwear to explain these differences. It has been suggested that exercising barefoot or wearing minimalist footwear provides greater stability than thicker midsoles due to increased glabrous epithelium sensory feedback (Bowser et al., 2017; Wyon et al., 2013). In the present study, the different footwear had limited effect on dynamic stability, except a significantly larger AP CoP amplitude (displacement) in barefoot and minimal (A) compared to the oversized (D) midsole (non-dominant leg). This finding does differ from the results of Bowser et al. (2017) and Wyon et al. (2013), but the different measure of dynamic postural stability may explain this.

CONCLUSION: Wearing shoes, particularly with larger midsole thickness, reduced peak vertical force and rate of loading without influencing dynamic stability when drop landing from 0.25 m, potentially reducing lower limb injury risk such as stress fractures.

REFERENCES:

Bowser, B.J., Rose, W.C., McGrath, R., Salerno, J., Wallace, J. & Davis, I.S. (2017). Effect of footwear on dynamic stability during single-leg jump landings. *International Journal of Sports Medicine*, 38(06), 481-486.

Fu, W., Liu, Y. & Zhang, S. (2013). Effects of footwear on impact forces and soft tissue vibrations during drop jumps and unanticipated drop landings. *International Journal of Sports Medicine*, 34(6), 477-483.

Malisoux, L., Gette, P., Urhausen, A., Bomfim, J. & Theisen, D. (2017). Influence of sports flooring and shoes on impact forces and performance during jump tasks. *PloS one*, 12(10), p.e0186297.

Martin, R.L., Irrgang, J.J., Burdett, R.G., Conti, S.F. & Swearingen, J.M.V. (2005). Evidence of validity for the foot and ankle ability measure (FAAM). *Foot & Ankle International*, 26(11), 968-983.

Robbins, S. & Waked, E. (1997). Balance and vertical impact in sports: role of shoe sole materials. *Archives of Physical Medicine and Rehabilitation*, 78(5), 463-467.

Wyon, M.A., Cloak, R., Lucas, J. & Clarke, F. (2013). Effect of midsole thickness of dance shoes on dynamic postural stability. *Medical Problems of Performing Artists*, 28(4), 195-198.

Yeow, C.H., Lee, P.V.S. & Goh, J.C.H. (2011). Shod landing provides enhanced energy dissipation at the knee joint relative to barefoot landing from different heights. *The Knee*, 18(6), 407-411.

Zadpoor, A.A. & Nikooyan, A.A. (2011). The relationship between lower-extremity stress fractures and the ground reaction force: a systematic review. *Clinical Biomechanics*, 26(1), 23-28.