
The Effects of Tempur Insoles on Ground Reaction Forces and Loading Rates in Running

CRYSTAL RUANO*¹, DOUGLAS POWELL‡², ELIZABETH T. CHALAMBAGA*², and DOUG RENSHAW*²

¹Andrews High School, Andrews, TX, USA; ²Department of Kinesiology, University of Texas of the Permian Basin, Odessa, TX, USA

*Denotes undergraduate student author, ‡denotes professional author

ABSTRACT

Int J Exerc Sci 2(3): 186-190, 2009. Runners often experience over-use injuries. Ground reaction force (GRFs) patterns have been associated with these over-use injuries; however, it is not solely the magnitude of GRFs, but also the rate at which they are applied that lead to lower extremity injury. Many recreational runners will use over-the-counter insoles as a method of treating or preventing injury. Therefore, the purpose of this study was to examine the efficacy of two insoles on peak GRFs and loading rates. It was hypothesized that no differences in peak GRFs or loading rates would exist with the addition of two insoles during running. Twelve subjects (7 females; 5 males) performed seven running trials in each of the following conditions: no insoles (NORM), over-the-counter insoles (OTC) and memory-foam insoles (TEMPUR). GRFs were recorded using a force plate (1440Hz; AMTI) while subjects ran across a 15 meter lab. A 2 x 3 (gender x insole) repeated measures ANOVA was used to compare the effects of insoles on loading rate and ground reaction forces. Alpha level was set at $p < 0.05$. The current study found no statistical differences in loading rate or GRFs between the insole and no insole conditions. Furthermore, there was no gender effect in any condition. The findings of the current study suggest that insoles do not attenuate shock or decrease loading rate. The lack of shock attenuation associated with insoles suggests they do not protect the lower extremity from injury.

KEY WORDS: Insoles, running, ground reaction forces

INTRODUCTION

Lower extremity injury is common in athletic events. Athletes often experience over-use injuries which may include stress fractures, tendonitis and patellofemoral syndrome (4-5, 7, 20). These over-use injuries are caused by repetitive stress on the structures of the lower extremity (12-15) and the risk of over-use injuries in an athlete is increased by poor lower extremity biomechanics during athletic movements

(2, 4-5, 12). The structure and function of the foot and ankle in shock attenuation has been shown to be a possible mechanism of injury for the lower extremity in repetitive loading tasks (4-5, 17). Specifically, hyper-pronation has been shown to create asynchrony between peak pronation and knee flexion (1, 17). Another mechanism of injury in repetitive loading tasks includes increased lower extremity stiffness which functionally reduces shock attenuation (8-9, 18, 21).

A common intervention for both hyperpronation and increased loading of the lower extremity is the use of shoe insoles and orthotics. The efficacy of shoe insoles and orthotics has yet to be established (3, 6, 10-11, 16, 19, 22). A plethora of insole and orthotic technology has been developed to aid the injury-prone runner. Many over-the-counter insoles are available for a variety of ailments and are often used by recreational runners after injury. A novel use of NASA technology includes the use of Tempur material in mattresses. This material has been shown to absorb impact and mold to the shape of containers. The author is unaware of research investigating the effectiveness of tempur material in shock attenuation as an insole. Therefore, the purpose of this study was to determine the efficacy of two types of insoles in altering loading rate during a running task. As the material properties of the insoles and their effectiveness in attenuating ground reaction forces was being examined, no posting was present in either type of insole. It was hypothesized that no differences would be observed between the insole conditions.

METHOD

Participants

Five males (age: 20.4 ± 2.4 years, body mass: 57.42 ± 4.87 kg, height: 1.6 ± 0.04 m) and seven females (age: 19.9 ± 1.3 years, body mass: 61.0 ± 12.2 kg, height: 1.7 ± 0.06 m) participated in the current study. Students were recruited from the campus of the University of Texas of the Permian Basin and the local Midland-Odessa area via word of mouth. All participants completed a medical history form and were apparently healthy at the time of data collection.

Participants in this study had not experienced injury to the lower extremity within the previous 6 months. All participants read and signed an informed consent approved by the institutional review board prior to participation in the study.

Instrumentation and Equipment

A force plate (1440 Hz, OR-6, AMTI, Watertown, MA, USA) was used to collect ground reaction forces. Movement conditions were determined by insole type and included: no insole (NORM), an over-the-counter insole (OTC) and a custom-made Tempur-pedic insole (TEMPUR). Subjects performed all trials in their personal shoes.

Testing Protocol

Standard anthropometric data were acquired including height, mass and age. Participants performed seven trials in each of three insole conditions: no insoles (NORM), over-the-counter insoles (OTC) and Tempur-pedic insoles (TEMPUR). A successful trial was described as the subject running across a 10 meter section of the lab in which the entirety of the foot contacted the force plate during the stance phase of the running gait. Subjects performed all trials at a self-selected pace and were not instructed in running style.

Data Reduction

The ground reaction force data were filtered using a low-pass filter with a cut-off frequency of 50Hz. Visual 3D (C-Motion, Inc., Rockville, MD, USA) was used to determine critical events including loading peak, time to loading peak and loading rate. Loading rate was defined as the

quotient of the loading peak and time to loading peak.

Statistical Analysis

A 2x3 (gender x insole) repeated measures analysis of variance was used to identify statistically significant differences between genders and between insole conditions. Alpha level was set at $p < 0.05$.

RESULTS

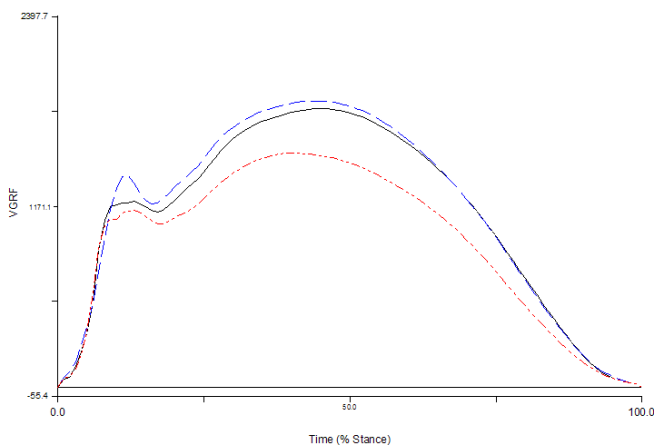


Figure 1. Ensemble vertical ground reaction force curves during running in the NORM (black; solid), OTC (blue; ---) and TEMPUR (red; -·-·-).

Data from three subjects (2 female and 1 male) were removed from the analysis as their running mechanics did not produce an initial loading peak decreasing the population to 9 participants.

No gender differences were present in vertical ground reaction force parameters. The addition of insoles did not produce statistically significant changes in vertical ground reaction forces ($p = 0.439$, Figure 1), time to peak vertical ground reaction forces ($p = 0.368$, Figure 1) or loading rates ($p = 0.520$, Figure 2). No gender or insole effects were observed in peak medio-lateral (gender: $p = 0.193$, insole: $p = 0.719$) or antero-

posterior ground reaction forces (gender: $p = 0.202$, insole: $p = 0.660$) during running.

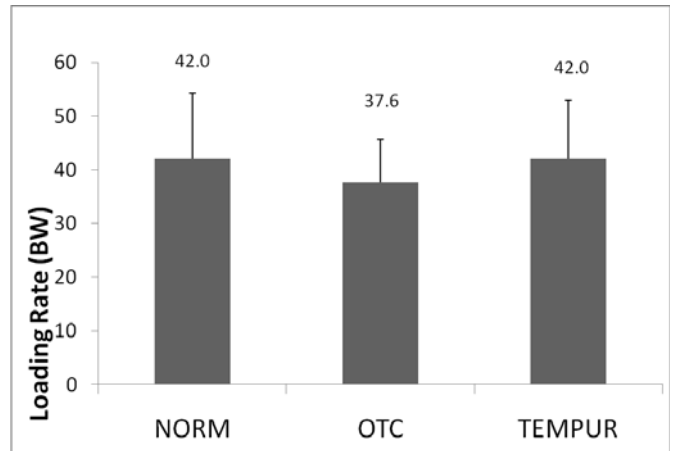


Figure 2. Loading rates in the NORM, OTC and TEMPUR conditions during a level running task.

DISCUSSION

The purpose of the current study was to examine the effects of the addition of two types of insoles on ground reaction force variables. The specific aim of the current project was to determine if the TEMPUR insoles aided in shock attenuation more than a standard over-the-counter insole. These data support the hypothesis that no differences exist between the two investigated insoles. The current data demonstrate that the addition of insoles did not reduce vertical loading rate or peak vertical ground reaction forces. It was expected that the TEMPUR insoles would aid in absorbing impact during loading response by extending the time to peak ground reaction force yielding decreased loading rates via the impulse-momentum relationship. However, the TEMPUR insoles did not reduce vertical ground reaction forces or time to peak vertical ground reaction force.

Though no statistical differences were observed, a visual trend of decreased loading rate was present with the addition of the OTC insole. The OTC insoles were designed and created with the intent of improving shoe comfort through shock attenuation using multiple densities of foam, though the TEMPUR insoles were custom-made by hand from a single layer of tempur material. The quality of the OTC insoles was much better, as would be expected from a marketed product. The differences in loading rates observed in the OTC insole condition were not statistically different from the TEMPUR insole or from the NORM condition, suggesting that these insoles did not produce a substantial change in loading rate. The sample size for the present study was small and a greater sample size may have lead to statistically significant differences between insole conditions. However, if these differences were statistically significant, they would likely not be substantial differences preventing injury to the lower extremity. It is possible that a marketed TEMPUR insole using a different density or multiple densities of TEMPUR material could provide advantages over currently marketed OTC insoles, however, our data provides evidence that this is unlikely.

While no differences were observed in the discrete data, subject feedback from participants strongly suggested that the TEMPUR insole was the more popular insole tested. The current data do not support the notion that the TEMPUR insoles were mechanically different from the OTC or NORM condition. Despite no mechanical advantages to the TEMPUR insoles, they may create unique afferent input to the central nervous system and the

benefits of a TEMPUR insole may not be kinetic in nature. Future research may focus on the kinematic assessment of running with these specific insole types. An investigation into the muscle activation patterns may also provide greater insight into the subjective preference of the TEMPUR insoles.

REFERENCES

1. Bates BT, James SL, Osternig LR. Foot function during the support phase of running. *Running* 3: 24-30, 1978.
2. Bates BT, Osternig LR, Mason B, James LS. Foot orthotic devices to modify selected aspects of lower extremity mechanics. *Am J Sports Med* 7(6): 338-342, 1979.
3. Ferber R, Davis IM, Williams DS. Effect of foot orthotics on rearfoot and tibia joint coupling patterns and variability. *J Biomech* 38(3): 477-483, 2005.
4. Hamill J, Bates BT, Holt KG. Timing of lower extremity joint actions during treadmill running. *Med Sci Sports Exerc* 24(7): 807-813, 1992.
5. James SL, Bates BT, Osternig LR. Injuries to runners. *Am J Sports Med* 6(2): 40-50, 1978.
6. Jenkins WL, Raedeke SG, Williams DS. The relationship between the use of foot orthoses and knee ligament injury in female collegiate basketball players. *J Am Podiatr Med Assoc* 98(3): 207-211, 2008.
7. Kaufman KR, Brodine SK, Shaffer RA, Johnson CW, Cullison TR. The effect of foot structure and range of motion on musculoskeletal overuse injuries. *Am J Sports Med* 27(5): 585-593, 1999.
8. Ledoux WR, Shofer JB, Ahroni JH, Smith DG, Sangeorzan BJ, Boyko EJ. Biomechanical differences among pes cavus, neutrally aligned, and pes planus feet in subjects with diabetes. *Foot Ankle Int* 24(11): 845-850, 2003.

INSOLES AND GROUND REACTION FORCES IN RUNNING

9. McClay I, Manal K. A comparison of three-dimensional lower extremity kinematics during running between excessive pronators and normals. *Clin Biomech* 13(3): 195-203, 1998.
10. Mundermann A, Nigg BM, Humble RN, Stefanyshyn DJ. Foot orthotics affect lower extremity kinematics and kinetics during running. *Clin Biomech* 18(3): 254-262, 2003.
11. Mundermann A, Nigg BM, Humble RN, Stefanyshyn DJ. Orthotic comfort is related to kinematics, kinetics, and EMG in recreational runners. *Med Sci Sports Exerc* 35(10): 1710-1719, 2003.
12. Nigg BM. Biomechanics, load analysis and sports injuries in the lower extremities. *Sports Med* 2(5): 367-379, 1985.
13. Radin EL, Martin RB, Burr DB, Caterson B, Boyd RD, Goodwin C. Effects of mechanical loading on the tissues of the rabbit knee. *J Orthop Res* 2(3): 221-234, 1984.
14. Radin EL, Paul IL. Response of joints to impact loading. I. In vitro wear. *Arthritis Rheum* 14(3): 356-362, 1971.
15. Radin EL, Yang KH, Riegger C, Kish VL, O'Connor JJ. Relationship between lower limb dynamics and knee joint pain. *J Orthop Res* 9(3): 398-405, 1991.
16. Stackhouse CL, Davis IM, Hamill J. Orthotic intervention in forefoot and rearfoot strike running patterns. *Clin Biomech* 19(1): 64-70, 2004.
17. Stergiou N, Bates BT. The relationship between subtalar and knee joint function as a possible mechanism for running injuries. *Gait Posture* 6: 177-185, 1997.
18. Williams DS, Davis IM, Scholz JP, Hamill J, Buchanan TS. High-arched runners exhibit increased leg stiffness compared to low-arched runners. *Gait Posture* 19(3): 263-269, 2004.
19. Williams DS, McClay Davis I, Baitch SP. Effect of inverted orthoses on lower-extremity mechanics in runners. *Med Sci Sports Exerc* 35(12): 2060-2068, 2003.
20. Williams DS, McClay IS, Hamill J. Arch structure and injury patterns in runners. *Clin Biomech* 16(4): 341-347, 2001.
21. Williams DS, McClay IS, Hamill J, Buchanan TS. Lower extremity kinematic and kinetic differences in runners with high and low arches. *J Appl Biomech* 17: 153-163, 2001.
22. Zifchock RA, Davis I. Non-consecutive versus consecutive footstrikes as an equivalent method of assessing gait asymmetry. *J Biomech* 41(1): 226-230, 2008.