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Research Article

The Examination of Midsole Construction on Bowling Footwear

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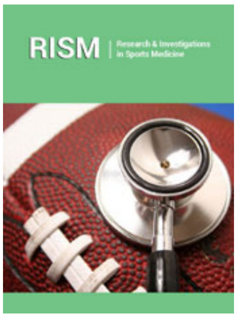
ISSN: 2577-1914



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Submission: October 07, 2022

Published: December 12, 2022

Volume 9 - Issue 2

How to cite this article: Tsung Lin Lu, Tom Wu*. The Examination of Midsole Construction on Bowling Footwear. Res Inves Sports Med. 9(2), RISM.000708. 2022.
DOI: 10.31031/RISM.2022.09.000708

Abstract

The purpose of this study was to examine the effects of midsole construction (barefoot, traditional bowling shoes with minimalist midsole design, and the modified bowling shoes with E-TPU midsole design) on the amount of shock absorption and the mechanics of bowling delivery. All shoes underwent static testing on top of a force platform. Twelve males (height 1.76±0.06m; weight 76.5±10.8kg; age 25±4 years old) volunteered for dynamic testing. Force plate data were recorded at 1,000Hz with Vicon Nexus software to evaluate the amount of shock absorption. Ariel Performance Analysis System software was used to measure the 2D body kinematic joint angles and velocities of hip, knee, and ankle, stride length, and linear ball velocity. The kinetic results indicated that the bowling footwear with the E-TPU material provided lower amount of initial peak vertical ground reaction force and rate of loading, which may potentially be beneficial to bowlers to minimize lower extremity injury. However, there was no significant difference found in the peak vertical ground reaction force with respect to each participant's body weight. The findings of this study provided an understanding on the effects of the E-TPU material on shock absorption in bowling footwear. The kinematic results indicated that no significant difference was found in the lower extremity for the joint angles and velocities of hip, knee, and ankle, stride length, and linear ball velocity. The findings of this study could help practitioners understand that midsole construction does not affect mechanics of bowling delivery and provide further understanding on the effect of footwear cushioning on athletic performance. Future studies are warranted to evaluate 3D motion analysis with experienced bowlers at the bowling alley and the internal joint forces and torques of bowling delivery mechanics.

Keywords: Bowling; Etpu; Kinematic; Kinetic; Midsole

Abbreviations: EVA: Ethylene Vinyl Acetate; PU: Polyurethane; BASF: Badische Anilinund Soda-Fabrik; E-TPU: Expanded Thermoplastic Polyurethane

Introduction

Bowling is one of the most popular indoor sports in the world and can be divided into several different categories that include five-pin, nine-pin, ten-pin, candlepin and duckpin. In all categories bowling footwear is required to play the game. Bowling shoes are similar to other athletic footwear that are constructed with three key principles: performance, injury protection and comfort. The current design of bowling shoes has the midsole portion made of minimalist leather for rental bowling footwear, and rubber, Ethylene Vinyl Acetate (EVA) or Polyurethane (PU) for athletic and performance bowling footwear, which may potentially influence mechanics of bowling delivery with various types of midsole design footwear. In addition, the design of bowling footwear outsole has a particular purpose as for sliding and braking in bowling delivery because bowlers need to take a stride, and slide and brake simultaneously to release the bowling balls. Therefore, the slick area of the outsole, usually made of microfiber, helps with the slide, while the traction pad, made of higher friction material like rubber, helps the bowlers to brake [1]. In the mechanics of bowling delivery, the lower extremity is crucial because the ability to slide the front foot consistently will affect bowler's ability to deliver the bowling ball more accurately [2]. Improper gait, mechanics, or footwear can possibly increase the risk of lower extremity injuries such as adductor muscle strains, ankle sprains, and knee ligament injuries [3,4] conducted an investigation to examine bowling-related injuries presenting to U.S. emergency departments. The report showed there were 8,754 injuries in bowling from 1990 to 2008, and the rate of occurrence on lower extremity injuries was approximately 14.9%. In addition, according to the National Electronic Injury Surveillance System in the United States, there was an average of 11,295 injuries each year between 2002 to 2014 in bowling.

The incident rate of knee injury was approximately 12%. Additionally, a recent research study was conducted to evaluate the injury rate of bowling during an intercollegiate bowling championship, and the results showed that the thigh and knee regions had an injury rate of 25.9% and 22.2%, respectively [5]. The high incident rate of bowling may also be attributed to unique bowling competitive rules and regulations. For example, a typical bowling competition consists of six games, and a standard bowling championship consists of five events including single, double, trios, group, and master. If a participant uses a five-step approach in his/her bowling delivery, he or she needs to deliver between 72 to 126 balls per event and also has to perform between 360 to 630 steps per event. On average each event takes between three to four hours to complete. Due to the repetitive of foot contact with the ground and long duration of the usage as in running, serious injury may occur in the lower extremity if proper bowling footwear is not worn. Hence, it is critical to investigate different footwear material for the midsole section of the bowling shoe in order to minimize lower extremity injury. Badische Anilinund Soda-Fabrik (BASF), the largest chemical company in the world, recently developed a material called Expanded Thermoplastic Polyurethane (E-TPU) which combines the properties of TPU with the advantages of foams, making shoes more comfortable to wear and providing greater shock absorption. The E-TPU can be molded into different shapes and forms which makes it flexible in design. The properties of E-TPU include lightweight, shock impact absorption, elastic, re-bound effect, softness, resilience, and durability [6].

However, the E-TPU material has yet been used in the bowling footwear. Therefore, the purpose of this study was to design the midsole section of bowling footwear using E-TPU material and to evaluate the amount of shock and force absorption that the bowling shoe with E-TPU material can sustain during bowling delivery, and to examine the effects of midsole construction on the mechanics of bowling delivery. The results of the study would enable practitioners to have a better understanding the effects of shock absorption on footwear with E-TPU material and the effects of footwear cushioning on athletic performance, so proper footwear can be worn by bowlers to increase athletic performance and to minimize lower extremity injury.

Methods

Participants and experimental design

One traditional bowling shoe with minimalist midsole design and one modified bowling shoe with E-TPU midsole design underwent the static performance testing. The static testing consisted of dropping a 0.5kg dumbbell inside a PVC pipe from a height of 0.61 meters at the heel cup region in each type of shoe on the AMTI force plate. Three trials in each condition for static tests were conducted with the same researcher to ensure the reliability of the test. The peak vertical ground reaction force (F_z) was recorded at 1,000Hz, and the Butterworth filter function was applied. Twelve healthy, college, right-handed recreational male participants (height 1.76±0.06m; weight 76.5±10.8kg; age 25±4 years old) volunteered for dynamic bowling testing. All participants used a candlepin bowling ball (mass: 1.1kg; diameter: 0.1m). Participants were asked to perform three different footwear conditions: barefoot, traditional bowling shoes with minimalist midsole design, and the modified bowling shoes with E-TPU midsole design. Four joint reflective markers were fixed to the right side of the participant's body at the greater trochanter of femur, lateral malleolus, lateral epicondyle of femur, the base of the fifth metatarsal, and three markers were fixed at the left side of the participant at the medial malleolus, medial epicondyle of femur, and the base of the first metatarsal. Data collection took place at the Biomechanics Laboratory. Five meters (16ft.) approach was marked with tape from starting line to the force plate. This distance was chosen because it is equal to the length of the lane approach in a bowling alley. AMTI force plate recorded at 1,000Hz with Vicon Nexus software (v. 1.8) to evaluate the amount of shock and force absorption.

Additionally, a Casio high speed camera (Model: EX-FH 25) was set up to capture the right sagittal view of motion of bowling ball delivery at 120Hz in conjunction with a 650 watts spotlight, so the effects of footwear on lower body mechanics could be examined. Twenty meters cushioning mat (64ft.) was placed on the ground behind the force plate in order to provide protection to the floor. Every participant was asked to bowl five balls in each type of footwear with maximum effort while rolling the ball straight. Every participant was asked to bowl five balls in each type of footwear with maximum effort while rolling the ball straight. A total of 15 balls were collected for each participant, and a total of 180 trials were collected in this study. Each participant had a one-minute rest between each ball and a three-minute rest between each type of footwear. Video trials from each type of footwear at the instant the ball released were selected and used for data analysis. Force plate data were recorded at 1000Hz with vicon nexus software to evaluate the amount of shock and force absorption. Ariel performance analysis system software was used to measure the 2D body kinematic joint angles and velocities of hip, knee, and ankle, stride length, and linear ball velocity. Digital filter function was applied with appropriate cut of frequency (x and y=9Hz). For the static testing, a t-test was conducted to compare the amount of vertical ground reaction force between the traditional bowling footwear with minimalist midsole design and the modified bowling footwear with E-TPU midsole design. For the dynamic testing, a one-way repeated measure ANOVA for the initial peak vertical force (F_z), the rate of loading, and peak vertical ground reaction force to body weight ratio were compared between three different footwear conditions. A one-way repeated ANOVA ($\alpha=0.05$) for the joint angles and velocities of hip, knee, and ankle, stride length, and linear ball velocity were compared between three different footwear conditions. Post hoc pairwise comparisons were conducted using t-test with bonferroni adjustment if a statistical significance was found.

Results

The results showed the modified footwear with E-TPU midsole had a statistical significant lower amount of vertical ground reaction force than the traditional footwear with minimalist midsole (Table 1). Being barefoot showed a substantial higher initial peak vertical ground reaction force 1,045.7±377.2N during the dynamic testing as compared to the traditional footwear with minimalist midsole 811.7±168.5N and the modified bowling footwear with E-TPU midsole 682.1±116.8N (Table 2). Being barefoot produced 100,265±75,332N/S of rate of loading during the dynamic testing compared to the traditional footwear with minimalist midsole's 25,830±25,770N/S and the modified footwear with the E-TPU midsole's 16,242±7,582N/S (Table 3). There was no significant difference found in the peak vertical ground reaction force with respect to each participant's body weight, the body weight did not have influence to the peak vertical ground force between footwear conditions (Table 4). The results of this study indicated that there was no statistically significant difference between barefoot, traditional footwear with minimalist midsole design, and the modified footwear with E-TPU midsole design in the hip, knee and ankle joint angles during the last step of bowling delivery (Table 5). Similarly, no significant difference was found in the joint angular velocities of hip, knee, and ankle (Table 6). Moreover, the mean stride length (p=0.314) did not show any significant difference between Barefoot 0.78±0.12m, Traditional .80±0.13m, and Modified .80±0.10m (Table 7). Also, no significant difference was found in the mean linear ball velocity (p=0.497) between barefoot 2.05±0.33 m/s, traditional 2.02±0.39m/s, and modified 2.01±0.39m/s (Table 7).

Table 1: Static testing at the heel cup region of bowling footwear.

Comparisons Between Footwear	Means±SD (Newton)	p
Traditional vs Modified	1,826.7±84.3 vs 907.7±33.8	0.005*

Source: *Statistical significant at p<0.05.

Table 2: Kinetic comparisons of the initial peak vertical force between footwear conditions.

Comparisons Between Footwear	Means±SD (Newton)	p
Barefoot vs Traditional	1,045.7±377.2 vs 811.7±168.5	0.008*
Barefoot vs Modified	1,045.7±377.2 vs 682.1±116.8	0.002*
Traditional vs Modified	811.7±168.5 vs 682.1±116.8	0.004*

Source: *Statistical significant at p<0.05.

Table 3: Kinetic comparisons of the rate of loading between footwear conditions.

Comparisons Between Footwear	Means±SD (Newton/Second)	p
Barefoot vs Traditional	100,265±75,332 vs 25,830±25,770	0.007*
Barefoot vs Modified	100,265±75,332 vs 16,242±7,582	0.002*
Traditional vs Modified	25,830±25,770 vs 16,242±7,582	0.128

Source: *Statistical significant at p<0.05.

Table 4: Kinetic comparisons of the peak vertical ground reaction force to body weight between footwear conditions.

Ratio	Means±SD			P
	Barefoot	Traditional	Modified	
Peak vertical force/body weight	1.35±.13	1.42±.23	1.38±.18	0.271

Source: *Statistical significant at p<0.05.

Table 5: Kinematic comparisons of the joint angle between footwear conditions.

Joint Type	Means±SD (Degree)			P
	Barefoot	Traditional	Modified	
Left Hip	92.3±9.9	94.0±10.3	93.9±9.9	0.289
Left Knee	133.0±14.5	131.9±12.4	132.1±14.5	0.758
Left Ankle	111.6±11.2	115.9±8.6	117.7±9.4	0.123

Source: *Statistical significant at p < 0.05.

Table 6: Kinematic comparisons of the joint velocity between footwear conditions.

Joint Type	Means±SD (Meter/Second)			P
	Barefoot	Traditional	Modified	
Left Hip	0.61±0.16	0.58±0.23	0.53±0.20	0.535
Left Knee	0.60±0.21	0.68±0.22	0.66±0.29	0.614
Left Ankle	0.58±0.19	0.58±0.32	0.53±0.29	0.764

Source: *Statistical significant at $p < 0.05$.

Table 7: Kinematic comparisons of the stride length between footwear conditions.

Joint Type	Means±SD (Meter)			P
	Barefoot	Traditional	Modified	
Stride	0.78±0.12	0.80±0.13	0.80±0.10	0.314

Source: *Statistical significant at $p < 0.05$.

Discussion and Implications

The findings of the static testing from this study were consistent with a previous running footwear research study on shock absorption [7]. Found the vertical ground reaction force from the same static testing was 2,962N for Vibram Five-fingers shoe, made of rubber bottom and minimalist cushion in attempt to mimic barefoot, compared to limited cushioned Nike Free Run's 775N and Adidas' traditional cushioned shoe of 872N. In this study the vertical ground reaction forces of the static testing for the traditional bowling footwear with minimalist midsole and the modified bowling footwear with the E-TPU midsole were 1826.6±84.3N and 907.6±33.8N, respectively. These findings were similar to Lloyd's study since both studies have demonstrated footwear that has greater and thicker cushion has the ability to attenuate greater amount of vertical ground reaction force.

Since landing is a critical part of movement in many sports skills, athletic footwear are designed with materials to address this movement in order to minimize injury [8] conducted a study to investigate the effects of athletic footwear on midsole thickness on the vertical force and the dynamic stability in single leg drop landing and found the initial peak vertical force on the non-dominate leg was 2,884±547N for barefoot, 2,726±480N for minimalist midsole, 2,536±453N for moderate midsole, 2,552±548N for thick midsole, and 2,437±506N for over-size midsole. Moreover, the rate of loading on non-dominate leg was significantly greater in the barefoot than the other four athletic footwear conditions with different thicknesses midsole design [8].

In this study the initial peak vertical force in the barefoot condition was significantly greater when wearing shoes. In addition, the rate of loading was significantly greater in the barefoot than in shoed conditions. Both studies demonstrated that footwear with greater and thicker cushioning has the ability to attenuate initial peak vertical force and the rate of loading. However, from a kinetic performance measure perspective, the modified footwear condition did not show significantly better shock absorption than the traditional and barefoot conditions since there was no significant difference found in the peak vertical ground reaction force with respect to each participant's body weight. Additionally, [9] conducted a study to examine the effects of various midsole densities of basketball shoes during landing activities, and the authors found that there was no significant difference in the hip and ankle joints for the range of motion and the maximal velocity between different midsole densities. Similarly, in this study significant difference was not found in the midsole cushioning and densities between barefoot, traditional bowling shoes with minimalist midsole design, and the modified bowling shoes with E-TPU midsole design in the lower extremity (hip, knee and ankle) joint angles and velocities during the last step of bowling delivery.

In the mechanics of bowling delivery, lower extremity is crucial because the ability to slide the front foot consistently will affect bowler's ability to deliver the bowling ball more accurately [2,10] conducted a study to examine elite level ten-pin bowlers delivery technique comparing different parameters between male and female bowlers. The authors found that the stride length between front toe and back toe at release were 1.16±0.20m for the male bowlers and 1.09±0.06m for the female bowlers. In this study there was no significant difference between three different footwear conditions (Barefoot: 0.78±0.12m vs Traditional: 0.80±0.13m vs Modified: 0.80±0.10m) for the stride length during the last step of releasing. The slight difference in the stride length of this study when com-pared with [10] study may be due to different skill levels, midsole constructions on bowling footwear, and type of bowling (candlepin vs ten-pin).

This study was conducted on the candlepin bowling, so the results may be different from the ten-pin bowling delivery since the mass of the bowling ball for the ten-pin is much greater, so a greater stride length may be needed in ten-pin bowling in order to provide better balance and stability during delivery. In addition, the linear ball velocity has commonly been considered as the reference of performance in many sports. In this study there was no significant difference found between the three different footwear conditions on the performance measure of the linear ball velocity at the instant of ball release. Some limitations should be considered in this study. The study was conduct-ed on candlepin bowling, which the results may be different from ten-pin bowling delivery since the mass of the bowling ball for the ten-pin is much greater.

This study used twelve male college aged students as participants, and the results may be different from that of more experienced bowlers as participants. Experienced or higher skilled bowlers may have better consistency in the mechanics of their bowling delivery which may improve the variability of the results. Moreover, this study used male participants as subjects, and the results may be different from having female participants to take part in the study. In addition, this study was conducted with two-dimensional analysis since the primary underarm motion of the bowling delivery occurred in the sagittal plane, and the participants in the study were asked to bowl the ball straight with maximum effort. Previous literature has also showed studies conducted with 2D motion analysis on softball windmill pitching with the similar rationale [11]. Nonetheless, future studies are warranted with a 3D motion analysis to obtain a comprehensive understanding of the bowling delivery. Furthermore, this study took place at the Biomechanics Laboratory, providing for a preliminary understanding on the mechanics of bowling delivery [12]. The results may be different from conducting the study at a bowling alley.

Conclusion

The purpose of this study was to examine the effects of midsole construction (barefoot, traditional bowling shoes with minimalist midsole design, and the modified bowling shoes with E-TPU midsole design) on the amount of shock absorption and the mechanics of bowling delivery. The results from this study indicated that bowling footwear with the E-TPU material provided lower amount of initial peak vertical ground reaction force and rate of loading. Moreover, the results from this study indicated no significant difference in the joint angles and velocities of hip, knee and ankle, stride length, the linear ball velocity and the peak vertical ground reaction force to body weight ratio between these conditions. The findings of this study provided a preliminary understanding on the effects of the E-TPU material on shock absorption in bowling footwear. In addition, the findings of this study suggested that midsole construction of bowling footwear has minimal impact to the mechanics of bowling delivery. This study provided an important preliminary understanding on the mechanics of bowling delivery. The results of the study enabled practitioners to have a better understanding on the effects of shock absorption on footwear with E-TPU material, so proper footwear can be worn by the bowlers to minimize initial impact force. Sports footwear developers may use this information to construct appropriate footwear to minimize injury. Future studies are warranted to examine and compare the E-TPU material footwear with the traditional cushion material footwear to assess if the E-TPU material is superior. Also, research can be conducted to evaluate 3D motion analysis with experienced bowlers at the bowling alley and the internal joint forces and torques of bowling delivery mechanics with the E-TPU material footwear to have a comprehensive understanding of bowling footwear development.

Acknowledgement

The authors would like to thank Bridgewater State University twelve male college students for participating in the study. In addition, the authors acknowledge the Bridgewater State University Dr. Mary Lou Thornburg Graduate Student Professional Development Fund.

References

1. DeMello M (2009) Feet and footwear: A cultural encyclopedia, UK, pp. 360.
2. Razman R, Abas W, Othman N (2010) Front foot slide variability and its relation to tenpin bowling performance. 28th International Conference on Biomechanics in Sports, pp. 1-2.
3. Hsiao KC, Chen MC, Tu CH (1996) Bowling injuries. Journal of Orthopaedic Surgery 13: 111-114.
4. Kerr ZY, Collins CL, Dawn Comstock (2011) Epidemiology of bowling-related injuries presenting to US emergency departments, 1990-2008. Clinical Pediatrics 50(8): 738-746.
5. Liu YC, Chung YC, Lin HY, Lee NH (2011) The sports injury analysis of Republic of China intercollegiate 98 academic year bowling championships. 2011 Cross-Strait Seminar on Science of Sports Training, pp: 111-113.
6. BASF (2017) The first expanded TPU.
7. Lloyd S, Wu T (2013) The examination of shock wave attenuation in running shoes. 31st international society of biomechanics in Sports: Chinese Journal of Sports Biomechanics 5(2): 339-341.
8. Soares D, Charalambous L, Rodrigues P, Mitchell A (2018) Effects of midsole thickness on single leg drop landing ground reaction force and dynamic stability. ISBS Proceedings Archive 36(1): 122.
9. National Electronic Injury Surveillance System (2017) Injuries caused by bowling.
10. Chu D, Zhang B, Mau K (2016) Tenpin bowling technique on elite players. International Conference on Biomechanics in Sports, pp. 1-3.
11. Ashley J, Wu T, Postlmayr C (2012) The examination of softball pitching fatigability in lower extremities. 36th Annual American Society of Biomechanics, USA.
12. Zhang S, Clowers K, Kohstall C, Yu Y (2005) Effects of various midsole densities of basketball shoes on impact attenuation during landing activities. Journal of Applied Biomechanics 21(1): 3-17.

