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ORIGINAL RESEARCH

CAN RUNNERS PERCEIVE CHANGES IN HEEL CUSHIONING AS THE SHOE AGES WITH INCREASED MILEAGE?

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ABSTRACT

Background: For those runners who utilize footwear and have a rearfoot strike pattern, the durability of the midsole heel region has been shown to deteriorate as shoe mileage increases.

Purpose: The purpose of this study was threefold: 1) to determine if the runner can self-report changes in heel cushioning properties of the midsole after an extended period of distance running, 2) to determine if force and plantar pressures measured in the heel region of the midsole using a capacitance sensor insole change after running 640 km, and 3) to determine if a durometer could be used clinically to objectively measure changes in the hardness of the material in the heel region of the midsole.

Study Design: Cross-sectional Study

Methods: Fifteen recreational runners voluntarily consented to participate and were provided with a new pair of running shoes. Each participant's running style was observed and classified as having a rearfoot strike pattern. Inclusion criteria included running at least 24 km per week, experience running on a treadmill, no history of lower extremity congenital or traumatic deformity, or acute injury six months prior to the start of the study. The ability of each participant to self-perceive changes in shoe cushioning, comfort and fit was assessed using the Footwear Comfort Assessment Tool (FCAT). In-shoe plantar pressures and vertical forces were assessed using a capacitance sensor insole while runners ran over a 42-meter indoor runway. A Shore A durometer was used to measure the hardness of the midsole in the heel region. All measures were completed at baseline (zero km) and after running 160, 320, 480, and 640 km. In addition to descriptive statistics, a repeated measures analysis of variance was used to determine if the FCAT, pressures, forces, or midsole hardness changed because of increased running mileage.

Result: While plantar pressures and vertical forces were significantly reduced in the midsole heel region, none of the runners self-reported a significant reduction in heel cushioning based on FCAT scores after running 640 km. The use of a durometer provided an objective measure of the changes in the heel region of the midsole that closely matched the reductions observed in pressure and force values.

Conclusion: The results indicated that runners who have a rearfoot strike pattern will have a 16% to 33% reduction in the amount of cushioning in the heel region of the midsole after running 480 km. Although there were significant reductions in heel cushioning, the experienced recreational runners in this study were not able to self-perceive these changes after running 640 km. In addition, the use of a durometer provides a quick and accurate way to assess changes in the hardness of the heel region of the midsole as running mileage increases.

Level of Evidence: 3, Controlled laboratory study

Key words: Durometer, force, midsole, plantar pressure, running

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INTRODUCTION

For those runners who utilize footwear when training, a major concern is the durability of the shoe midsole which serves to provide cushioning when impacting the supporting surface. Since previous research suggests that runners using shoes will have a greater tendency to have a rearfoot strike, the durability of the heel region of the midsole is of particular concern.[1,2] Runners can experience impact forces of 2.5 times body weight when the shoe collides with the ground[3] and typically there are approximately 600 to 750 foot strikes per km while distance running.[4] Thus, the durability of the running shoe midsole is a major consideration when deciding when to purchase new footwear. The two most common materials used in midsole construction are ethylene vinyl acetate (EVA) and polyurethane (PU).

One of the first studies to assess the deterioration of running shoe midsole materials was conducted by Cook, et al.[5] In their study, a mechanical impact tester was used to assess midsole durability in addition to two experienced runners. They tested 13 different running shoes that all had midsoles constructed from EVA. They reported that with mechanical impact testing the running shoes tested retained less than 60% of the initial shock absorption capacity between 400 to 800 km of wear. The degree of midsole degradation that resulted when the two experienced runners used the same running shoes was only a 20% to 30% reduction between 480 and 640 km. In an attempt to overcome the differences between mechanical and in-vivo testing of midsole durability, Hamill and Bates assessed six healthy male runners using the same shoe with a dual-density EVA midsole while running over a force platform at running intervals separated by 140 km.[6] All runners in the study ran in excess of 48 km per week for three years prior to the start of the study. Although they reported a loss of 7.3% in the shock absorbing capability of the shoe after running 420 km, the magnitude of the loss was much less than reported by Cook, et al. Hamill and Bates also noted that the runners' ability to "sense" the performance characteristics of the shoe may be misleading since reasonable functional changes in the midsole occurred during the initial 300 to 400 km of wear. This inability of the runner to "sense" degradation of midsole cushioning could be a factor in the development of running related injuries since Kong, et al have shown that as running shoe cushioning capability decreases, runners modify their running pattern to maintain constant external loads and that the adaptation strategies used by runners were not affected by different cushioning technologies (i.e.; air, gel).[7] In a more recent study, Schwanitz and Odenvald assessed durability of the heel region of the midsole using mechanical impact testing and reported a 20% reduction in shock absorption characteristics of the midsole after simulating approximately 600 km of running.[8] While Wang, et al assessed midsole cushioning at 50 km increments using a mechanical impact tester, they had eight male amateur runners run in the test shoes for 500 km.[9] They reported a significant decrease in cushioning but the reduction was only 5%. In the only study to date that has attempted to use an in-shoe pressure sensing insole to assess midsole durability, Verdejo and Mills reported that plantar pressures in the heel region increased on average by 100% after three healthy males ran 500 km.[10] All three runners were rearfoot strikers and utilized shoes with an EVA midsole. The increase in plantar pressures was attributed to fatigue of the EVA foam causing the material to become harder.

In interpreting the research to date, it would appear that mechanical testing over-estimates the degradation of the cushioning properties of the EVA midsole when compared to in-vivo testing of midsole durability. Authors of in-vivo studies to date have reported that the degradation of midsole cushioning can occur after running anywhere between 480 to 640 km. In responding to a runners' inquiry as to when they should buy a new pair of running shoes to ensure adequate cushioning, it is important for the clinician to know 1) if the runner can self-perceive a degradation in midsole cushioning, especially in the heel region if they are a rearfoot striker, and 2) whether there is a simple test that can be done in the clinic to assess possible degradation of the midsole.

Mundermann, et al developed a Footwear Comfort Assessment Tool (FCAT) to allow the runner to self-report their satisfaction with shoe comfort, fit and cushioning.[11] The FCAT consists of nine 100 millimeter visual analogue scales that assesses overall comfort, heel cushioning, forefoot cushioning, pronation-supination control, arch height, heel cup fit, shoe heel width, shoe forefoot width, and shoe length. The left end of the all nine scales or zero (0 millimeters) was labeled "not comfortable at all" and the right end of the scale (100 millimeters) was labeled "most comfortable condition imaginable." The higher the score for all nine scales the better the comfort, fit and cushioning. Mundermann, et al reported that the FCAT had excellent levels of reliability for all scales if a control condition was used before each session the FCAT was utilized.[11] In attempting to find a simple tool that could be used in the clinic to assess the hardness of the EVA foam, Barton, et al reported excellent levels of reliability between three raters using a hand-held durometer to assess the hardness of the midsole in the heel region at the point where the center of the heel contacts the midsole within the shoe.[12] While Barton, et al provide the clinician with a test to consistently measure the hardness of the midsole, it is unknown if assessing the hardness of the midsole in the heel region with a durometer would be sensitive enough to assess degradation of the midsole over an extended period of running.

After an extensive review of the current literature, the authors could not find any studies that have assessed runners' self-perceived changes in heel cushioning provided by the midsole or whether a durometer to test midsole hardness in the heel region of the midsole would be effective over an extended period of distance running. Thus, the purpose of this study was threefold: 1) to determine if the runner can self-report changes in heel cushioning properties of the midsole after an extended period of distance running, 2) to determine if force and plantar pressures measured in the heel region of the midsole using a capacitance sensor insole change after running 640 km, and 3) to determine if a durometer could be used clinically to objectively measure changes in the hardness of the material in the heel region of the midsole. Three hypothesizes were developed for this study. First, those individuals who run at least 24 km per week would be able to perceive a reduction in the heel cushioning when running in the same pair of shoes over a running distance of 640 km (approximately 400 miles). Second, that the use of a durometer could be used to objectively measure changes in midsole material hardness in the heel region of running shoes used by the same runner over a running distance of 640 k. Third, that reductions in force and plantar pressures in the rearfoot or heel region of the midsole would not be greater than between 20% and 30% after running 640 km.

METHODS

Subjects

Fifteen recreational runners (4 male; 11 female) with a mean age of 26.3 (sd = 4.4) years volunteered to participated in this study. All participants were recruited from the greater Flagstaff, Arizona, region using advertisements in printed media and notice boards. All runners selected had no previous history of surgery, childhood or congenital disorders, fractures or dislocations to the lumbar spine, lower extremity, ankle or foot. In addition, none of the runners had a history of a trauma or pain to either the lower extremity, ankle and foot, or lumbosacral regions for at least six months prior to start of the investigation. All the participants had consistently run at least 24 km per week for two years prior to the start of the study. Each participant's running style was visually observed by one of the investigators (TGM) and all 15 runners were classified as having a rearfoot strike pattern. The Northern Arizona University Institutional Review Board approved the study procedures and each participant signed an informed consent prior to taking part in the study.

After signing the informed consent, each runner was provided with a $120.00 voucher to purchase a pair of running shoes from a local athletic shoe store. Each participant made an appointment with the storeowner, who was an experienced runner, and upon arriving at the store underwent a treadmill running analysis performed by the owner to determine the best running shoe for the individual. Ten of the female runners selected a Brooks Ravenna running shoe, one female selected Saucony Ride running shoe and the four males selected an Asics GT 2140 running shoe. All three types of running shoes selected by the runners had a standard ethylene vinyl acetate (EVA) midsole or a biodegradable midsole with material properties very similar to EVA. All participants were instructed not to use their new running shoes until they returned to see the primary investigators.

Instrumentation

To assess in-shoe plantar pressure and vertical force data, a Novel PEDAR® capacitance sensor insole (Novel USA, Minneapolis, MN) was used with a sampling rate of 50 Hz. Hurkmanns, et al has reported good repeatability with the PEDAR® insoles when used to measure vertical force and pressure between multiple days of measurement.[13] The PEDAR® capacitance sensor insole consisted of a matrix of 90 to 100 capacitance transducers and was approximately 2 mm in thickness. All six pairs of sensor insoles used in the study were calibrated prior to the start of data collection using a rubber bladder that was pressurized with compressed air over a range beginning with 5 kPa and ending with 600 kPa. The cables from the sensor insoles were attached to a Bluetooth enabled device worn by the runner that transmitted data to the computer. Thus, the participant was not tethered to the computer with cabling when running over the 42-meter runway. To assess the hardness of the midsole material, a Shore type A durometer (Model 1500; Rex Gauge Company, Inc., Buffalo Grove, IL) was utilized. The measurement obtained using a Shore type A durometer results in a value between 0 and 100 with higher values indicating a harder material.

Procedures

Upon arriving for the initial data collection session, each participants body weight and height were obtained. They were then asked to don their new running shoes and walk for one mile followed by a two-mile run for two consecutive days to "break-in" the new shoes. Once the shoe "break-in" period was completed, the participant returned to complete the initial FCAT as well as measurement of midsole hardness and in-shoe pressure assessment. As previously noted, Mundermann, et al reported that the FCAT had excellent levels of reliability for all nine scales if a control condition was used before each session the FCAT was utilized.[11] For this study, the control shoe condition was a martial arts shoe with soft leather upper and a hard, flat rubber outsole (Tiger Claw Martial Artist's Athletic Shoes, Pioneer Interstate, Inc., Nashville, TN). The martial arts shoe was selected as the control shoe condition instead of a standard running based on Mundermann, et al who reported that the control shoe condition should not have a similar density in comparison to the actual shoe density being tested.[11] The original cushioned sock liner (insole) from the martial arts shoe was removed and replaced with a piece of non-molded Aliplast 10 material with a thickness of three millimeters (Alimed, Inc, Dedham, MA). Aliplast 10 is a firm, closed cell polyurethane material with durometer of 58 (Shore A gauge). The participant was then asked to run at a self-selected speed used for a typical training run over a 42-meter indoor runway three times. Once they completed the practice runs in the control shoe, they were asked to don their running shoes and repeat running the same distance at the same self-selected running speed. Running speed was monitored using two infra-red photocells position 20 meters apart (Tandy Corp., Fort Worth Texas) and connected to a digital timer (model 54030; Lafayette Instrument Co, Lafayette, Indiana). To control for possible variations in the cushioned sock liner (insole) of the running shoe and to only assess the cushioning provided by the running shoe, prior to beginning their run the insole was removed from the running shoe and replaced with a piece of 3 mm non-molded Aliplast 10 material to ensure the inner aspect of the shoe was standardized for all shoes. When the participant completed running the three practice trials over the 42-meter runway with their running shoes, the participant was asked to immediately sit down and complete the FCAT after receiving verbal instructions by the same investigator (MWC). While they were completing the FCAT, another investigator (TGM) assessed the hardness in the heel region of the running shoe using the Shore type A durometer. The measurement was made within the shoe directly on top of the midsole at the center of the heel and three centimeters from the most posterior aspect of the shoe with the Aliplast 10 material removed (see Figure 1). The average of three consecutive durometer measurements was recorded. After the durometer measurement was completed, the Aliplast 10 material was placed back in the shoe and an appropriately sized PEDAR capacitance sensor insole was placed on the top of the Aliplast 10 material. The participant was then asked to run at the same self-selected pace over a 42-meter indoor runway while capacitance sensor data were collected and running speed was monitored as previously described. For all capacitance sensor data collection, the subject was

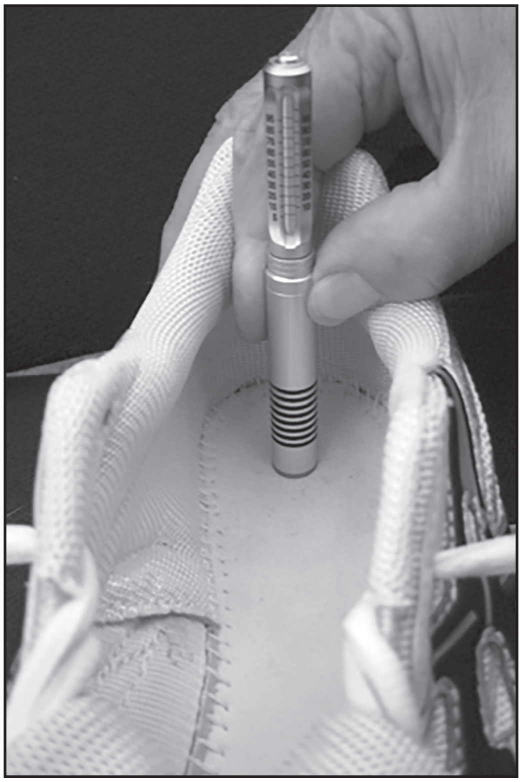

Figure 1. *Measurement of midsole hardness in the heel region of the running shoes using the durometer.*

asked to not wear socks to prevent any possible cushioning effects of the sock on the capacitance sensor data. When questioned about not wearing socks, each participant indicated they did not believe that his or her gait pattern had changed when running without socks and this was confirmed by observation of each runner's gait pattern by the investigators during data collection. Following the completion of the capacitance sensor data collection, each participant was instructed to follow their usual running regime using study footwear and was provided with a calendar to log the distance run per day. Participants were instructed to notify the investigators after they had completed running 160, 320, 480, and 640 km so they could return and have all the measures described above repeated. To ensure that the participant ran at the same speed for baseline and all follow-up assessments, the maximum variation in the self-selected running speed allowed was less than 5%.

Data Analysis. The FCAT ratings for each of the nine scales provided by the participants at the initial assessment and after running 160, 320, 480, and 640 kilometers were measured in mm from the zero point to determine the value of each scale related shoe comfort, fit and cushioning. To determine the change in plantar pressure and vertical forces, ten foot strikes for the right foot only were randomly selected from the middle 15 meters of the 42-meter run. This was done to ensure that participants were neither accelerating nor decelerating from their self-selected running speed during data collection. The selection of ten foot strikes for the analysis of force and pressure data was based on the findings of Kernozek, et al, who reported high levels of reliability across all foot regions with at least nine steps while using the PEDAR insoles.[14] Once the ten foot strikes were selected for each participant, the Percent Mask program (Novel USA, Minneapolis, MN) was used to divide each step into the following six plantar regions: medial rearfoot, lateral rearfoot, medial midfoot, lateral midfoot, medial forefoot, and lateral forefoot. These plantar regions were determined based on a percentage of total foot length and width and were consistently applied to all ten steps selected for analysis. The heel region was from 0% to 30%, the midfoot region from 30% to 60%, and the forefoot from 60% to 85% of total foot length. The total widths of the rearfoot, midfoot, and forefoot were divided in half. Once all the regions were defined, the Multimask Evaluation program (Novel USA, Minneapolis, MN) was used to calculate the pressure-time integral (PTI) and force-time integral (FTI) for the medial and lateral heel regions. The PTI and FTI were also selected for analysis since these two variables assess the magnitude of plantar pressure and vertical force applied during the time the medial and lateral heel regions are in contact with the supporting surface. The values for the PTI and FTI for both heel regions for all ten foot strikes were averaged and used for further statistical analysis.

Statistical Analysis

In addition to descriptive statistics, a series of independent t-tests were used to determine differences existed in demographics between the female and male runners. Repeated measures analysis of variance (ANOVA) tests were performed to determine if the FCAT, FTI, PTI, or heel midsole hardness changed because of running mileage. Post hoc comparisons were performed to determine differences among the test conditions. An alpha level of 0.05 was used for all tests of statistical significance.

RESULTS

The demographic data for all 15 subjects is provided in Table 1. All 15 runners were able to complete the required 640 km of running with the study footwear within 32 weeks from the first day of testing. The results of the t-tests indicate that there were no significant differences between the female and male subjects for age, body weight, or BMI. The only demographic variable that was significantly different was height. Based on these results, all statistical analysis was performed on all 15 subjects regardless of gender.

Table 1. *Demographic information on the subjects used in this study. Values in parentheses are standard deviations*

	All Subjects (n=15)	Males (n=4)	Females (n=11)
Age (years)	26.3 (4.4)	28.5 (4.2)	25.6 (4.4)
Height (cm)	168.7 (9.1)	177.8 (8.4)	165.4 (7.1)
Weight (kg)	63.0 (7.7)	68.9 (5.8)	60.9 (7.4)
BMI (kg-m^2)	22.2 (2.3)	21.8 (1.8)	22.3 (2.5)

Self-Perceived Shoe Comfort, Fit, and Comfort

Footwear Comfort Assessment Tool (FCAT) scores for each of the nine variables measuring self-perceived shoe comfort, fit, and comfort decreased over the course of running 640 km. These decreases ranged from 2.7% for Heel Cushioning to 10.4% for Pronation-Supination Control (Table 2). Despite these slight self-perceived reductions in perceived shoe comfort, fit, and cushioning over time, based on the repeated measures ANOVA none of the nine variables were found to be statistically significant.

Midsole Hardness

The durometer values indicating the hardness of the midsole in the heel region are shown in Table 3. Between baseline and 640 km, heel midsole hardness increased approximately 17%. The results of the repeated measures ANOVA for the heel region durometer values were significantly different (p = .000) as running mileage increased. The results of post hoc tests indicated that the increase heel hardness was significantly different from baseline to: 160 km (p = .001), 320 km (p = .001), 480 km (p = .008) and 640 km (p = .000).

Table 2. *Subject perceived shoe comfort and fit while running up to 640 kilometers as assessed using the Footwear Comfort Assessment Tool (FCAT). The values listed for each comfort variable are based on a 0 to 100-millimeter visual analogue scale with standard deviation in parentheses.*

Comfort Variable	0 km	160 km	320 km	480 km	640 km	Percent Decrease	p Value
Overall Shoe Comfort	83.6 (9.6)	78.2 (13.4)	80.3 (13.0)	78.9 (14.1)	78.3 (14.3)	6.3 (2.3)	0.244
Heel Cushioning	80.3 (13.2)	81.5 (10.1)	79.2 (15.2)	80.2 (15.2)	78.1 (19.3)	2.7 (1.3)	0.947
Forefoot Cushioning	82.4 (11.1)	77.4 (12.6)	80.6 (16.2)	72.4 (20.8)	75.0 (14.1)	9.0 (4.1)	0.171
Medial Arch Comfort	78.4 (17.3)	76.8 (16.2)	78.7 (17.4)	74.1 (16.7)	74.3 (16.4)	5.2 (2.2)	0.863
Heel Cup Fit	84.3 (9.8)	83.9 (9.1)	80.2 (15.7)	80.0 (14.9)	81.9 (13.6)	2.8 (2.0)	0.538
Heel Width Fit	85.1 (11.3)	82.0 (10.4)	81.9 (13.9)	82.6 (14.2)	79.7 (14.9)	6.3 (1.9)	0.513
Forefoot Width Fit	82.2 (12.3)	77.8 (19.6)	78.4 (19.4)	76.5 (18.2)	73.7 (22.8)	10.3 (3.1)	0.559
Length Fit	80.0 (16.8)	83.9 (11.0)	79.5 (13.3)	82.0 (13.0)	76.8 (16.5)	4.0 (2.7)	0.168
Pronation-Supination Control	82.9 (7.6)	75.5 (17.1)	74.9 (16.3)	73.3 (15.4)	74.3 (14.2)	10.4 (3.8)	0.146

Plantar Pressure and Vertical Force

PTI values decreased approximately 20% in the medial heel and 28% in the lateral heel as the number of miles ran increased. The results of the repeated measures ANOVA for PTI were significantly different for both the medial (p = .009) and lateral heel (p = .000) as running mileage increased. Post hoc tests indicated significant differences (p < .05) between baseline and 320 km for the lateral heel compared to 480 kilometers for the medial heel (Table 4). Like the findings for PTI, FTI values also decreased approximately 16% in the medial heel and 33% in the lateral heel as the number of miles ran increased. The results of the repeated measures ANOVA for FTI were significantly different for both the medial (p = .003) and lateral heel (p = .000) as running mileage increased. Post hoc tests indicated significant differences (p < .05) between baseline and 320 km for the lateral heel and between baseline and 480 km for the medial heel (Table 4).

Table 3. *Change in durometer values of the midsole over time. Durometer measurements were obtained using a Shore type A durometer (Model 1500; Rex Gauge Company, Inc., Buffalo Grove, IL) with a higher value indicating a harder material*

	DUROMETER VALUES
Km	HEEL REGION
Zero (0)	36.2 (2.5)
160	41.5 * 6.3)
320	40.8 * (5.2)
480	40.8 * (6.4)
640	42.3 * (6.4)

*Significantly different from zero (0) kilometers (p<.05)

DISCUSSION

Previous research has not assessed the ability of the runner to self-perceive changes in heel cushioning provided by the midsole when using the same pair of running shoes over an extended period of distance running. Thus, one purpose of this study was to determine the ability of the runner to self-report changes in the heel cushioning properties of the midsole in a new pair of running shoes at baseline and after running 160, 320, 480, and 640 km. These mileage distances were selected based on previous research demonstrating that typical midsole degradation in the heel region occurs prior to or at 640 km. To assess changes in the midsole cushioning properties, the PTI and FTI for the medial and lateral heel regions were assessed using an in-shoe capacitance sensor insole. Between baseline and after running 480 km, both the PTI and FTI showed reductions in the amount of midsole heel cushioning of approximately 16% to 33% with no further significant reductions after running 640 km. As would be expected

Table 4. *Mean plantar pressure and force values under the heel at baseline and every 160 kilometers run. The values in parentheses are standard deviations*

Variable	km	Medial Heel	Lateral Heel
Pressure-Time Integral (kPa*Sec)	0	19.7 (5.3)	20.8 (4.8)
	160	18.7 (3.5)	19.7 (3.8)
	320	17.5 (3.5)	16.7 (3.4) *
	480	15.9 (5.0) *	14.8 (4.9) *
	640	16.8 (4.1) *	15.0 (3.5) *
Force-Time Integral (N*sec)	0	22.7 (5.9)	27.6 (7.3)
	160	22.0 (4.2)	25.4 (5.8)
	320	20.9 (4.5)	21.6 (5.5) *
	480	19.1 (6.7) *	18.4 (6.0) *
	640	19.7 (5.3) *	19.1 (4.7) *

* Value is statistically different from baseline (Zero (0) km); p<.05

since most runners with a rearfoot strike pattern tend to load the lateral aspect of the heel region of the midsole when initially contacting the supporting surface, the lateral heel region demonstrated a more rapid reduction in heel cushioning for both the PTI and FTI, than the medial heel region. Significant changes in midsole heel cushioning, based on both PTI and FTI data, were observed between baseline and 320 km for the lateral heel region but not until 480 km for the medial heel region. While these reductions in the PTI and FTI, which represent the degree of midsole degradation in the heel region, are very similar to values previously reported in the literature,[6,8] none of the 15 runners self-reported a significant reduction in midsole cushioning after running 640 km. In fact, the percent decrease noted by the runners in this study using the FCAT was the least for heel cushioning (2.7%) in comparison to the other eight scales assessing comfort, fit and forefoot cushioning. Based on these findings, the first hypothesis that stated individuals who run at least 24 km (15 miles) per week would be able to perceive a reduction in the midsole cushioning when running in the same pair of shoes over a running distance of 640 km was rejected. In addition, the third hypothesis which stated that reductions in force and plantar pressures in the medial and lateral heel region of the midsole would not be greater than 20% after running 640 km was also rejected since reductions in the PTI and FTI were 28% and 33% respectively after running 480 km. The runners' inability to self-perceive a loss in the level of cushioning provided by the heel region of the midsole could be attributed to the increased thickness of the midsole in the heel region. While the thickness of the midsole in the forefoot of the running shoes used in this study was 1.6 centimeters, the heel region thickness was 2.8 centimeters. While recent researchers have attributed the increased thickness of the heel region of the midsole as a factor that facilitates a rearfoot strike pattern during running,[1] Robbins, et al were the first to suggest that the increased cushioning provided by running shoes can act to attenuate the perceived magnitude of forces acting on the plantar surface of the foot.[15] The findings of the current study would appear to support the theory proposed by Robbins and colleagues.[15]

Since it would appear that the runner may not be able to self-assess changes in the cushioning properties of the heel region of the midsole, the ability to quickly and objectively assess changes in the hardness of the material in the heel region of the midsole would be of value to the clinician. In the current study between baseline and after running 640 km, heel midsole hardness increased approximately 17% based on durometer measurements, which is similar to the decreases noted in both the PTI and the FTI. Based on these findings, the second hypothesis which stated that the use of a durometer could be used to objectively measure changes in midsole material hardness in the heel region of running shoe midsole used by the same individual over a running distance of 640 km was not rejected. The durometer used in this study was easy to use and with a cost of $250.00 is feasible in those clinical settings that specialize in the evaluation and management of running injuries. In the current study, the running footwear for each participant was assessed using the durometer prior to using the shoes which provided a baseline value for comparison. While the authors recognize that it is not always practicable in the typical clinical setting, for those clinicians who provide services or consult with high school or collegiate athletic teams or recreational running clubs, baseline durometer measurements of the midsole can be made during pre-running season screenings that would allow the clinician assess changes in midsole material hardness at a later date. Future studies are also needed to provide baseline durometer readings for various types of midsole materials.-

It is unclear whether a reduction in the ability of the shoe midsole to absorb forces or plantar pressures is a factor in the development of running injuries. Based on the results of their prospective study, Taunton, et al have suggested that as the running shoe ages with use, running injuries can increase as the cushioning and support qualities of the shoe decline.[16] More recently, Kong, et al demonstrated that as shoe cushioning decreases, individuals modify their running patterns to maintain constant external loads and that the adaptation strategies due to shoe degradation were not affected by different cushioning technologies.[7] Although the development of running injuries is multifactorial, irrespective of the specific influence of the running shoe on the development of running-related injuries, current evidence would support the need for the clinician to assess midsole cushioning as part of the physical examination of the runner.

Limitations of the current study include the limited number of runners recruited to participate and that all runners in the study utilized a rearfoot strike pattern. The restriction in the number of runners who took part in the study was directly due to the cost of providing new footwear for all participants. Although only 15 runners participated, the ability to follow the change in midsole hardness, vertical forces and plantar pressures from baseline or zero to 640 km in a new pair of running shoes provides important information on self-perception and midsole durability. While only runners with a rearfoot strike pattern were selected for participation, the focus of this study was to assess the degree of cushioning degradation in the heel region of the midsole of the running shoes. The fact that previous studies have shown that the rearfoot strike pattern is the most common amongst recreational and collegiate cross-country runners would justify the selection of individuals that use a rearfoot strike pattern when running.[17,18]

CONCLUSION

The results of this study indicate that runners who have a rearfoot strike pattern, when using a new pair of running shoes with an EVA or a biodegradable midsole with material properties, will have a 16% to 33% reduction in the amount of midsole heel cushioning after running 480 km. The degree of reduction will be greater in the lateral heel region of the midsole in comparison to the medial heel region. It would appear that even though these reductions in heel cushioning are significant, experienced recreational runners are not able to self-perceive these changes in cushioning after running 640 km. In addition, based on the findings of this study the clinician can utilize a durometer to quickly and accurately assess changes in the hardness of the heel region of the midsole as running mileage increases.

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