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THE ACUTE AND CHRONIC EFFECTS OF HIGHLY CUSHIONED SHOES ON LOADING CHARACTERISTICS IN RECREATIONAL RUNNERS

Jessica Corkin
Northern Michigan University, jcoullar@nmu.edu

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By

Jessica Lynn Corkin

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THE ACUTE AND CHRONIC EFFECTS OF HIGHLY CUSHIONED SHOES ON LOADING CHARACTERISTICS IN RECREATIONAL RUNNERS

This thesis by Jessica Lynn Corkin is recommended for approval by the student's Thesis Committee and Department Head in the Department of Health and Human Performance and by the Assistant Provost of Graduate Education and Research.

Committee Chair: Dr. Scott N. Drum Date

First Reader: Dr. Sarah Clarke Date

Second Reader: Dr. Michael Bohne Date

Third Reader: Dr. Michael Stoolmiller Date

Assistant Dean & Director: Dr. Elizabeth Wuorinen Date

Dr. Lisa S. Eckert Date
Interim Director of Graduate Education

ABSTRACT

THE ACUTE AND CHRONIC EFFECTS OF HIGHLY CUSHIONED SHOES ON LOADING CHARACTERISTICS IN RECREATIONAL RUNNERS

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Jessica Lynn Corkin

Recently, highly cushioned shoes (HCS) entered the running market, and manufacturers suggested extra cushioning potentially reduced injury rates through superior shock absorption, implying less impact upon foot strike versus other shoes. Hence, the purpose of this study was to examine the effects of a 4-week HCS intervention on running-related impact forces in adult recreational runners. We hypothesized HCS would result in altered force attenuation compared to standard cushioned shoes (SCS) at baseline. After 4-weeks, we speculated differences would not be attenuated. Twenty-nine healthy runners (18-60 yrs of age) who had never worn HCS were randomized to either an intervention (INV) or control (CON) group, and wore HCS or SCS, respectively, a majority of each training week. During pre and post-tests in a lab, all participants wore SCS first, followed by HCS, while running overground at a self-selected pace and striking embedded force plates in up to 30 total trials/session, 10 trials/shoe, to obtain impact peak (PK1) and active peak (PK2) force, instantaneous loading rate (ILR), average loading rate (ALR), and contact time (CT). Runners also recorded daily training data for 4-weeks. A repeated measures, mixed ANOVA was utilized to detect differences between shoes and groups. Our hypotheses were not supported. No differences were found at baseline or after the 4-week intervention between shoes and groups. In conclusion, HCS do not cause alterations in ground reaction forces over a short-term habituation period in recreational runners.

Keywords: highly cushioned shoes, running, ground reaction force, force plate, kinetics

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LIST OF SYMBOLS AND ABBREVIATIONS

Average loading rate……………………………………………………………………ALR

Active peak force………………………………………………………………………PK2

Contact time…………………………………………………………………………….CT

Control group…………………………………………………………………………..CON

Ground reaction forces…………………………………………………………………GRF

Highly cushioned shoes………………………………………………………………..HCS

Impact peak force……………………………………………………………………….PK1

Instantaneous loading rate……………………………………………………………...ILR

Intervention group……………………………………………………………………...INV

Peak force………………………………………………………………………………...PF

Standard cushioned shoes………………………………………………………………SCS

CHAPTER 1: JOURNAL MANUSCRIPT; Targeting *Medicine & Science in Sports & Exercise*

Introduction: Running has become a nationwide phenomenon over the last 30 years (7), with an increase in participation, particularly in competitive races. Over 40 million Americans run regularly (24), with 2 million competing in long-distance races, defined as half marathons or marathons (12). Besides those who run competitively, many also run recreationally due to its low cost and ease of access. Some may choose running for its positive influence on one's physical wellness as well as reduction in diseases and chronic health problems (16); others may use it as a starting point for a fitness program. However, despite the potential decreased risk of cardiovascular and metabolic diseases, running's association with high impact forces can result in a variety of lower extremity injuries (30).

Injuries are prevalent among runners, with reports stating that within a 12 month period, 31.6% to 57.1% of runners suffer from a lower extremity injury (16). Many of these injuries include those linked to stress-related injuries, such as tibial stress fractures (6, 7, 21). Stress fractures are thought to be linked to a dosage of loading over time, potentially signified by a combination of peak shock, ground reaction force (GRF) load rates, and the repetitive nature of running (34). Thus, many shoe manufacturers have designed several types of shoes to attempt to reduce the stresses that running places on the body (44).

In previous studies, researchers have found shoe characteristics can impact the amount and type of stresses on the musculoskeletal system (29, 53). Midsole hardness can stimulate changes in muscle activity of the lower extremity (53). Other authors have found cushioned shoe characteristics can alter running style, such as foot strike (37), while others have determined shoe degradation over time can increase stance time and induce lower maximum ankle dorsiflexion and higher plantar flexion during toe-off (28). Despite technological advances in shoes and shoe characteristics, running injuries have not decreased over the last 30 years (13).

Recently, highly cushioned shoes (HCS) entered the shoe wear market and coincided with the trend of minimalist or marginally cushioned shoes. Importantly, HCS are defined as running shoes with markedly thicker midsoles and up to 2.5 times more cushioning versus standard cushioned shoes (SCS) (44). HCS manufacturers vaguely claim their shoes provide more shock attenuation upon impact, thereby reducing injury risk (22).

Most runners utilize a rear foot strike (RFS) pattern, meaning the heel makes first contact with the running surface while one is in locomotion (19) . Cushioning in the heel and midsole is believed to reduce the rate of loading and decrease injury risk (29). The calcaneus, or bone of the heel, being both rigid and stiff, can lead to higher impact peak forces and load rate in comparison to forefoot strikers who initially land with the first one-third of their foot in locomotion (29). Previous studies have documented that vertical impact loading and loading rates have been associated with injuries in runners (8, 34). Therefore, shoe designers have added cushioning in the soles of the shoes in order to theoretically counteract impact forces and increase shock absorption.

Many types of shoe styles have become popular in recent years for a brief period of time, but many studies have focused primarily on minimalist shoes and SCS (17, 55). A variety of studies on standardized cushioned shoes in comparison to other shoes, such as minimalist and rocker shoes, have also been conducted (9, 14, 20, 33, 49, 53). Rocker shoes can be defined as those that have a rounded bottom and similar properties with HCS, with more cushioning than SCS. These shoes have been used in clinical populations to assist in the treatment of lower body musculoskeletal disorders, and has been shown to improve these conditions (26, 50). Rocker shoes have been found to reduce the plantar flexion moment significantly to assist patients with Achilles tendinopathy (50). Longer term interventions have also been conducted using rocker shoes (5, 46). They have also been used by diabetics who have peripheral neuropathy (15). However, for general populations, the rounded bottom creates a less effective base for the shoe and generates more instability (15). HCS are classified as meta-rockers, which as manufacturers state, create a roll from initial impact to toe-off (54).

Several studies on minimalist shoes have indicated that they minimize injury risk and increase running economy (45, 49, 52). Conversely, increasing the cushion beyond that of a SCS increases energy expenditure (49); furthermore, more cushioning can increase instability at the foot, potentially leading to higher injury risk over time. Little research has been conducted on long term usage of HCS, and no prior research has determined if a 4-week intervention would affect biomechanical parameters.

Richards, Magin, and Callister (40) described the usage of cushioning in running shoes based on four assumptions: (1) impact forces during running are a major source of injury, (2) running on hard surfaces causes high impact forces, (3) cushioned shoes potentially decrease impact forces to a less harmful level, and (4) the potential for shoe cushioning to directly cause injury is minimal. Notably, the evidence for these assumptions varies. Researchers assessed kinetic variables prior and following a run, finding significant differences between SCS and HCS in ALR (average loading rate) and ILR (instantaneous loading rate) both before and after a 5 kilometer run; however, there was no main effect for time (5).

In one study by Chambon and colleagues, researchers found no significant difference in impact transient or loading rate between shoes of varying midsole thicknesses after an acute bout of running in each (9). No difference in peak vertical GRF between an acute bout in SCS vs. HCS was found by Strang et al. (51). Aminaka et al. found acute trials across overground force plates in HCS yielded a significantly higher ILR in HCS but no difference in ALR (1).

Additionally, decreased proprioception has been characterized as a negative side effect of HCS (41). Some have argued this reduced ability to precisely monitor one's impact and foot position leads to increased risk of injury (40). Overall, the lack of research on HCS indicates the effect of cushioning on injury rates in runners remains relatively unknown (16).

Thus, a few studies have been conducted on acute effects of HCS (8,23,28), but to our knowledge no long-term interventions or habituation research designs have been completed on a recreational running population. In order to determine if there was a change or attenuation in potential adverse running mechanics after runners adjusted to HCS, the effects of HCS on various running-related impact force measurements were studied in the current intervention. We hypothesized a statistically significant difference would occur at baseline between shoe types (i.e., pooled data, SCS vs. HCS) and the difference would be maintained at posttest irrespective of training group. We based this on some of the past HCS studies. Therefore, the purpose of this study was to examine the effects of a 4-week HCS intervention on running-related impact forces in adult recreational runners.

Methods:

Experimental Approach to the Problem: A repeated measures, longitudinal, experimental design was used. After completion of appropriate paperwork, fitting and purchase of HCS from a local running store, and baseline testing, runners were randomized to either the intervention (INV) or control (CON) and continued to train for four weeks, per their normal weekly running routine. INV runners were instructed to run in HCS a majority of the time each week. CON runners maintained their normal running routine in their SCS. After each run, participants documented the date and time, mileage, duration, type of terrain, weather pattern(s), average rating of perceived exertion, and any associated discomforts or pain specific to various body regions in the running log given to them. Post 4-weeks, runners returned with their detailed logs to undergo post-testing.

Subjects: A total of 29 volunteers participated in the study. Those who were experienced, recreational runners who trained consistently for 3-5 days per week over the previous two months and at least 10 miles per week were recruited. Potential participants were contacted/recruited via email and social media from the Upper Peninsula of Michigan, including students and faculty from the local university and runners from the community.

Inclusion criteria involved the following: between the ages of 18 and 60 years, ran in HCS twice or less in the past year, apparently healthy by the American College of Sports Medicine (ACSM) standards, answered "no" to all of the questions in the physical activity readiness questionnaire (PAR-Q), and no musculoskeletal injuries within the past year. Exclusion criteria included the following: lower extremity injury in the last 12 months, determined as any injury that caused halting of training for more than a week; less than two months of endurance running experience; and previous, consistent use of HCS. Those who met the inclusion criteria and were not excluded due to any of the preceding factors could participate. The participants completed informed consent, PAR-Q, and a running survey paperwork. To double check if the initial, verbal or written inclusion/exclusion criteria were effectively met, the aforementioned forms were analyzed for any inconsistencies; those runners who did not meet criteria were exempt from participation.

Participants were not compensated financially for participation in the study but were allowed to keep the HCS used in the study. The CON group did not receive their HCS until after the posttests to prevent usage of the shoes during the intervention. HCS may have served as an incentive for participants interested in trying these shoes at no financial cost.

Procedures: Before the 4-week intervention period, runners were randomized into CON (i.e., did not wear HCS during 4-week training period) or INV (i.e., wore HCS during the 4-week training period) groups with all testing performed in a pre- and post-test format. Each group was formed such that the same number of male and female participants existed. Testing took place at the local university's Exercise Science Laboratory. During both testing periods/lab visits (i.e., pre- and post-tests), participants were asked to refrain from intense workouts the day before and of testing, to come hydrated and well-fed as per a normal day of training, and to bring their usual SCS used in training. Height was measured via a stadiometer (Tanita digital scale BWB-800A, Tokyo, Japan) and mass measured via a digital scale (Seca, Chino, CA, USA). Participants then warmed up on a treadmill for five minutes at a self-selected pace equivalent to a leisurely long run pace or a rating of perceived exertion of 2 or 3 (light feeling of exertion) out of 10 (maximal exertion).

Participants were then designated a starting place for their practice runs, approximately 20 meters from two imbedded (into the floor/ground) force plates (AMTI, Watertown, MA, USA). They were instructed to mimic the pace from the warm-up and run across the room over the force plates as naturally as they could without targeting the plates. Participants could land on both force plates, as data was reduced simultaneously from both. Timing gates (Microgate, Mahopac, NY, USA) allowed for more accurate pacing and the research team gave verbal feedback and encouragement to each participant regarding appropriate, consistent running speed. An "x" was on the wall beyond the force plates at an approximate eye level, and participants were encouraged to focus on it as they ran over the plates. They practiced running across the imbedded force plates at their standardized speed for familiarization in both speed and accuracy of the right foot landing on the force plate(s) for several trials during each shoe condition.

Familiarization was followed by running up to 15 trials in the SCS condition in order to achieve up to 10 successful trials. Note, from a standardized viewpoint, at pre- and post-test, runners were always assessed in SCS first, followed by HCS; it also enhanced the novelty of wearing HCS for the first time at pretesting after becoming acclimated to the force plates in SCS. A trial was considered successful if it met the following criteria: it was within 0.2 m/s of their standardized speed, if the entire right foot landed on one or both of the force plates, and if the participant ran naturally over the force plates (i.e., did not target or track the plates visually). During the first lab visit (pre-test) and after the first set of SCS trials, subjects put on their HCS for the first time and ran for five minutes on the treadmill at the same self-selected speed selected prior to the SCS condition. Every participant had the same HCS model that had an approximate 30 mm midsole. They then repeated familiarization trials in HCS followed by up to 15 data collection trials in order to achieve approximately 10 successful footstrikes on one or both force plates. Interestingly, from a complete anecdotal perspective, when most of the participants put on the HCS for the first time, they almost unanimously said the shoes felt awkward, well cushioned, and seemed to throw off their normal sensation of running mechanics/form, in particular during the very first overground session targeting the force plates. Over several trials the awkwardness seemed to dissipate.

Immediately after pretesting procedures were completed, participants were told their group assignment (i.e., CON or INV) and instructed on the course of action over the following four weeks. Those in INV were provided with HCS; CON left their HCS locked in the laboratory to prevent usage. Participants were also instructed on how to document their runs in the specified training log. They immediately began the four week, normal training period the next day.

Specifically, during the four weeks, participants randomized to INV began running with HCS a majority of their training sessions each week (e.g., if they ran 3 x week, then wore HCS at least 2 x; if they ran 4 x week, then wore HCS 3 x week; if they ran 5 x week, then wore HCS at least 3-4 x; and so on). Participants randomized to CON continued to use their own SCS for the 4-week experimental period. All runners were instructed to continue with their normal, weekly running routine and maintain 10 miles per week or greater, per their normal habit. After each run, all participants documented the date and time, mileage, duration, type of terrain, weather pattern, average rating of perceived exertion, type of shoe worn, and perceived pain in various body regions using a pain scale. After the 4-week intervention period, the subjects returned to the university Exercise Science Laboratory with their detailed logs to repeat the same testing conducted at baseline in the same shoe order, along with having their running logs collected for later analysis. Both groups were given their HCS shoes to keep/take home after post-testing.

For data reduction, all forces were normalized to body weight to allow standardization of the data among participants and trials for each variable were averaged for each participant. From the force plate data, impact peak (PK 1), active peak (Pk 2), vertical average loading rate (ALR), vertical instantaneous loading rate (ILR), and contact time (CT) were calculated. Impact peak (Pk 1) was measured as the highest vertical force in the first 20% of the stance phase. Active peak (Pk 2) was quantified as the highest vertical force between 20% and 80% of the stance phase. Vertical average loading rate (ALR) was determined by dividing the impact peak magnitude by the time to impact peak. Vertical instantaneous loading rate (ILR) was determined as the maximum increase in vertical force in the first 20% of stance for each trial. Contact time was determined by calculating the length of time in which 20 N or more of vertical force was applied to the force plate.

Statistical Analysis: A 2x2 mixed ANOVA (group X time and shoe X time) was performed to determine significance with confidence interval set at p=0.05. Effect sizes were reported using partial eta^2 (ηp^2). Effect size interpretation was based on the scale for effect size classifications of Cohen (11). This scale is based on f-values for effect size with the following classification: 0 to 0.29 = small, 0.3 to 0.49 = moderate, and 0.5 or greater is large (11). All analyses were performed using SPSS version 24.0 (SPSS, Inc., Chicago, IL, USA) and Microsoft Excel 2013 version 14.0 (Microsoft Corporation, Redmond, WA, USA).

Forty-four participants completed the required paperwork to participate, but twenty-nine participants completed the entire study and their data was used in analysis. One participant from the SCS group dropped from the study due to decreased mileage over the four week period. Four participants from the HCS experienced adverse reactions (e.g., bruising, numbness, throbbing pain in the foot/feet) and were instructed to stop wearing the HCS. All other participants completed the four week experimental period and post-tests. However, ten more were excluded after posttests due to unsuccessfully achieving (i.e., hitting the force plate(s) correctly) five or more trials out of 15 total trial in both shoe conditions over both the pre and post-testing periods.

Results: Descriptive statistics for group mileage and percent HCS use are displayed in Table 1. Descriptive statistics for all variables for all tests, shoes, and groups are presented in Table 2. Descriptive statistics with p-values and effect sizes for between shoe differences during the pre-test are reported in Table 3. Table 4 displays within-subject factors of shoes over time, groups over time, and shoes and groups over time.

At pretesting, when comparing pooled data in SCS to HCS, no significant differences were found and all effect sizes were small. The acute (i.e., at baseline testing) response to the shoes yielded no statistically significant difference between shoe types. Additionally, there was no statistically significant difference between shoes over time ($p > 0.05$). There was no statistically significant difference between the groups over time (p

>0.05). MILR was the variable closest to significance (p=0.066) with a small effect size (0.120). Refer to figure 1 for an illustration of MILR in both groups across time.

Discussion: The purpose of this study was to examine the effects of a 4-week HCS intervention on running-related impact forces in adult recreational runners. We hypothesized a statistically significant difference would occur at baseline between shoe types (i.e., pooled data, SCS vs. HCS) and the difference would be maintained irrespective of training group. Our hypotheses were not supported; no difference between group or shoe type occurred.

Notably, previous research exists on the acute but not chronic (e.g., 4-weeks of training) effects of HCS on impact forces. Described in an abstract (i.e., no published paper from the data), Ruder and colleagues initially found significant differences in ALR and ILR in recreational runners, which differs from the present data (43). In that study, the participants ran on a treadmill for three minutes in each condition at a self-selected speed, and 15 steps were collected, whereas the present study used plates imbedded in the floor. The treadmill likely created consistency within each runner but may not have been akin to running over ground.

Treadmill usage in research has been a topic of debate, as several factors can cause biomechanical differences between overground and treadmill running. Accommodating to changes in visual and auditory and any fear resulting during treadmill running may lead to biomechanical differences (48). Differences in air resistance may also result (23), and intra-strike belt speed disparities can cause changes in kinematics (47). However, some researchers have found that the treadmill can be a moderate to highly valid tool for assessing vertical ground reaction forces in runners who have a consistent landing pattern during treadmill and overground running (27). However, this is one of few studies focusing on impact peak and loading rates, potentially warranting further study. In the study by Ruder et al., standardization of treadmill speed within participants led to a more controlled study, perhaps producing less trial-trial variability and therefore allowing for any small differences between the shoes to be statistically represented due to less variation in the data.

Comparing ALR and ILR in SCS and HCS in overground trials before and after a 5 kilometer treadmill run in both SCS and HCS, Carter and colleagues (10) in their abstract found significant differences between shoes. Their results yielded no shoe-time interactions but resulted in significant differences for ALR and ILR between shoe types, which is inconsistent with our findings at pretesting. However, our study used the format of warm-up, acclimation trials, and test trials repeated for each shoe type; whereas Carter et al. conducted trials before and after a 5k run for each condition on separate days.

No difference in peak vertical GRF between an acute bout in SCS vs. HCS was found by Strang et al. (51). Aminaka and colleagues found no difference in loading rate between shoe types (1). Both aforementioned studies are consistent with the current findings. Another study that compared shoes of varying midsole thicknesses yielded no difference in shoes for transient peak of vertical GRF and loading rate (5). This study was similar to the present one in that participants also ran across imbedded force plates, but the shoe midsoles ranged from 0 mm 16 mm, while our study used HCS that were approximately 30 mm. Based on the research by Strang et al., Aminaka and colleagues, and the present study, increasing midsole thickness does not yield a statistically significant difference in comparison to SCS.

Stress-related injuries are thought to be linked to a dosage of loading over time, potentially by a combination of peak shock, GRF load rates, and the repetitive nature of running (34). Loading rate is often associated with increased injury risk over time, and the researchers who found increased ALR in HCS speculated it could lead to higher injury risk (10, 43). However, our study found no difference, signifying over a four week period, there was no increased ALR or ILR in runners wearing HCS the majority of the time. It should be noted we did not track injury rate, but it can be hypothesized that injury rate did not increase in HCS. Notably, 4 of the 22 in the INV group dropped out due to adverse reactions, which yielded an 18% drop out rate due to adverse effects. These reactions consisted of bruising of the medial aspect of the foot arch, throbbing pain while wearing HCS, and numbness that persisted during prolonged running. A recent study by Malisoux, Chambon, Urhausen, and Theisen (2016) yielded results indicating that a higher drop (i.e., height difference between the toe box and heel of the shoe) leads to a higher injury risk in runners using SCS (31). There was variance in the drop height in the SCS of the four participants who had to leave the study early, with drop height ranging from 0 mm to 10mm. Transitioning to shoes with an altered drop (6mm in the HCS) in addition to a thicker midsole may have increased injury risk. Future researchers may want to standardize drop height in SCS runners in order to prevent any interaction from drop height.

It is to our knowledge no chronic studies have been performed on HCS in a pre- and post-test format. However, there are many researchers who focused on transitioning from one footwear style to another, such as SCS to minimalist, or SCS or minimalist to barefoot running. Several of these studies had an intervention duration of seven weeks or longer (36, 45), whereas the present study's intervention duration was four weeks. This short study period served as a limitation and we speculate it may have prevented significant changes or differences between shoe type and groups.

Another factor that may have influenced the results was the instruction for the INV group to run in their own SCS at least once per week during the intervention period; we surmised this to be the safest method to introduce the HCS group to potentially hazardous outcomes (i.e., injury from too much cushioning). In a study that appears to be the first of its kind, runners who rotated between shoes decreased their risk of injury in comparison to runners who switched between shoes over a 22 week period (32). Researchers ascertained that this rotation might serve as a protective factor, potentially leading to a variation of the load placed upon the musculoskeletal system (32). Although there is a difference in experimental periods, our study included 11 runners who regularly rotated between running shoes before the study (6 in CON, 5 in INV), potentially adding a protective factor to reduce or maintain rates of loading over time.

There are several limitations in this current study. The duration of the experimental study was four weeks and may not have been long enough to see a potential alteration in force parameters, as other studies involving transitioning to minimalist shoes, for example have lasted seven weeks or longer (35, 45). The testing took place in October and November, limiting the duration due to the unpredictable running weather during that time of year in the Midwest. Researchers in the future may want to utilize a longer intervention period, which would benefit runners interested in long-term HCS usage.

Additionally, the running speed was not standardized across the group of participants, leading to potential variations in the kinetic values for slower vs. faster runners. No familiarization session was conducted outside of the practice trials before each condition in the pre and posttests. Future researchers may be interested in conducting a separate session in which participants become acclimated to running over the force plates naturally and consistently. This would assist in preventing the elimination of participants during data reduction who did not reach the minimum number of trials to be included in the analysis.

Previous studies have found that shoe characteristics can influence the extent and type of stresses on the musculoskeletal system (29, 53). Technology over the previous thirty years has not resulted in a decrease in running injuries (13). More research is needed to determine if cushioning can alter GRF over weeks or months and if there is an association with injury risk. A four week intervention period yielded no difference between SCS and HCS, suggesting HCS usage may not lead to higher loading rates, thus not increasing injury risk in relation to loading over time.

Conclusion: We found no statistically significant difference at baseline between shoe types and no difference between groups over time on all variable (i.e., Pk1, Pk2, ALR, ILR, CT). Therefore, this study indicated no alternation of select overground, biomechanical measures in HCS over a 4-week running period. We theorize HCS do not increase injury risk due to no change in impact forces vs. SCS, but caution should be warranted when transitioning to different running shoe types with varying midsole characteristics. Rotation between various shoes until habituation to a new shoe, for instance, is recommended to decrease injury risk.

Table 1. Means and standard deviations for weekly mileage and HCS usage during experimental period for control and intervention groups.

	Weekly Mileage (mi)	Percentage of Runs Wearing HCS (%)
CON	16.61 ± 5.30	0
INV	16.44 ± 6.85	69.53 ± 10.91

Table 2. Means and standard deviations of kinetic parameters for first impact peak (PK1), second impact peak (PK2), average loading rate (ALR), maximum instantaneous loading rate (MAX-ILR), and contact time (CT).

TIME	GROUP	SHOE	PK1 (x BM)	PK2 (x BM)	ALR (x BM /s)	MAX-ILR (x BM /s)	CT (s)
Pre	Control	SCS	1.999 ± 0.214	2.415 ± 0.271	43.999 ± 19.115	128.537 ± 52.916	0.256 ± 0.028
		HCS	2.002 ± 0.205	2.415 ± 0.249	42.391 ± 16.952	123.876 ± 36.807	0.257 ± 0.024
	Intervention	SCS	2.004 ± 0.241	2.433 ± 0.315	42.064 ± 15.667	127.222 ± 51.865	0.254 ± 0.037
		HCS	2.061 ± 0.285	2.443 ± 0.297	43.680 ± 16.085	133.371 ± 69.258	0.255 ± 0.037
Post	Control	SCS	2.055 ± 0.181	2.385 ± 0.243	46.910 ± 17.913	111.587 ± 40.436	0.257 ± 0.025
		HCS	2.055 ± 0.217	2.393 ± 0.231	45.746 ± 22.509	108.399 ± 38.468	0.258 ± 0.028
	Intervention	SCS	2.130 ± 0.305	2.402 ± 0.314	53.276 ± 22.468	136.407 ± 67.454	0.257 ± 0.039
		HCS	2.089 ± 0.300	2.399 ± 0.305	52.814 ± 33.213	129.302 ± 75.286	0.258 ± 0.034

Table 3. Descriptive statistics of shoe differences at baseline with p-values and effect sizes.

	SCS	HCS	Diff	p-value	Effect size
Pk1	2.00 ± 0.22	2.03 ± 0.24	0.03	0.23	0.13
Pk2	2.42 ± 0.29	2.43 ± 0.27	0.01	0.81	0.04
ALR	43.06 ± 17.25	43.01 ± 16.26	0.05	0.97	0.003
Max_ILR	127.90 ± 51.47	128.46 ± 54.11	0.56	0.94	0.01
CT	0.26 ± 0.03	0.26 ± 0.03	0.00	0.60	0.00

Table 4. Within-subject factors of shoes over time, groups over time, and shoes and groups over time.

WITHIN-SUBJECT FACTORS		BETWEEN SUBJECT FACTORS	PK1		PK2		ALR		MAX-ILR		CT	
			p-value	np^2	p-value	np^2	p-value	np^2	p-value	np^2	p-value	np^2
SHOE	TIME	-	0.120	0.087	0.894	0.001	0.794	0.003	0.278	0.043	0.805	0.002
-	TIME	GROUP	0.644	0.008	0.567	0.012	0.182	0.065	0.066	0.120	0.490	0.018
SHOE	TIME	GROUP	0.138	0.080	0.652	0.008	0.688	0.006	0.178	0.066	0.898	0.001

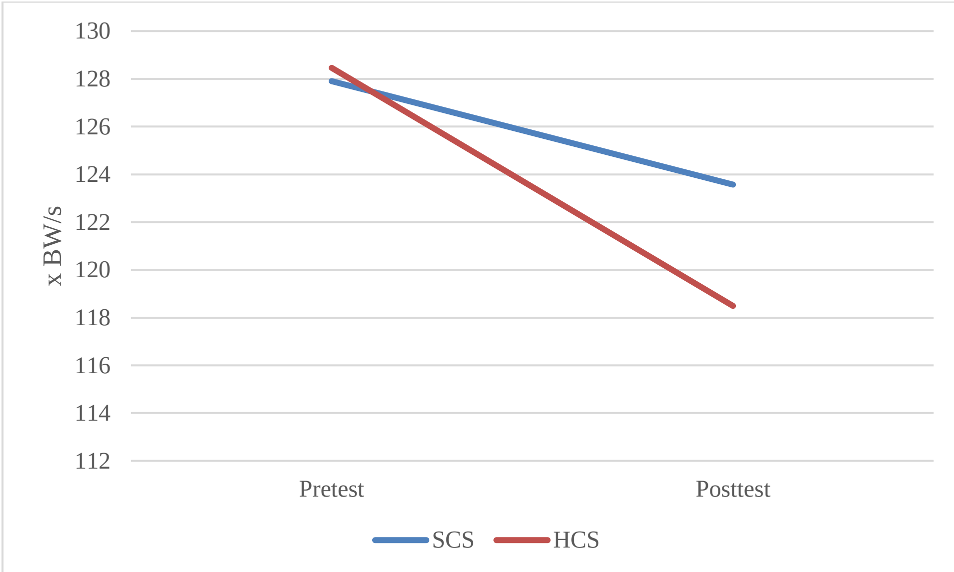

Figure 1. Pooled maximum instantaneous loading rate (MILR) across groups over time.

Figure 2. HCS utilized in study.

CHAPTER II: LITERATURE REVIEW

Introduction

Running is an action humans have participated in for thousands of years; however, the modern running shoe was not created until the 1970s (37). The history of running shoes dates back to ancient Greece, where running sandals were created to provide traction for runners (35). As competitive events increased in popularity in early civilization, running sandals evolved, becoming more advanced. The start of the early Modern Olympic Games brought about heavy boots and shoes for marathoners, eventually leading to a transformation in early running shoes (35). Through the centuries, running shoes continued to evolve, and with the 1900s emerged many brands considered eminent today: Reebok, Puma, Adidas, and ASICS (35).

In recent years, manufacturers have shifted to minimalist shoes with low cushioning due to theoretical advantages of barefoot or minimalist running (24). Several researchers have found these shoes have advantages over thicker soles or standard cushioned shoes (SCS), such as decreased impact forces and encouragement of a forefoot strike (FFS) pattern, which has been shown to decrease lower limb loading rate (38). In contrast, some manufacturers recently created highly cushioned shoes (HCS) and claim this newer design increases shock absorption (22). Notably, despite promotion of reduced ground reaction forces (GRF) when wearing HCS, these companies have provided little research to support their claim(s). Furthermore, several research groups focusing on GRF and other force measurements, various shoe thicknesses, and shoe types have produced varying results, including a statistically significant difference in ALR and IRL between shoe types (43) and no difference in loading characteristics between shoes of varying midsole thicknesses (1, 51). Therefore, more research is needed to determine the acute and chronic effects of HCS on loading characteristics.

The purpose of this review was to examine five major sections: (a) Prevalence of Running and Related Injuries, (b) Kinematics of Running, (c) Acute Effects of Shoe Cushioning, (d) Long Term Interventions of HCS, and (e) Summary of Literature.

Prevalence of Running and Related Injuries

Running has been a part of millions of people's lives since early civilization. Individuals of all ages have engaged in it with very little financial expenditure or equipment requirements. Over 40 million people per year participate in running, with 17 million completing a distance race in 2016 (12, 25). With this high level of participation the potential for greater injury rate is apparent. It is estimated that 30-70% of runners incur some form of injury each year (16), and not surprisingly these consist mainly of overuse injuries (6, 21). Such injuries include medial tibial stress syndrome, Achilles tendinopathy, plantar fasciitis, and patellar pain (30). Plantar fasciitis, one of the more common maladies, can be caused by a variety of factors: excessive running or adding too much mileage in a short period of time, using faulty (e.g., poor fit, too stiff, zero drop) running shoes, running on stiff surfaces, or having a cavus foot or short Achilles tendon (6). Additionally, runners in particular are at increased risk of stress fractures, which account for 15–20% of all musculoskeletal-related injuries (3) and can be related to variables such as vertical impact peak (VIP), instantaneous loading rate (ILR), and vertical average loading rate (VALR) (21).

In experienced runners, two of the most prevalent injuries are plantar fasciitis and medial tibial stress syndrome (30). Medial tibial stress syndrome is common due to the constant recruitment of the soleus and flexor digitorum muscles, which stress the periosteum of the tibia and causes inflammation (30). Stresses applied by the muscles and vertical ground reaction forces cause difficulties with bone remodeling and causes detrimental effects. Plantar fasciitis can be attributed to using a heel strike while running, generating high repetitive forces, which causes breakdown of the plantar fascia and pain (30). These conditions lead to long-term negative effects that can affect runners in everyday life outside of running.

Researchers in other studies have found impact forces can increase when runners wear softer midsole shoes or run on softer surfaces, increasing injury risk (2, 4). Baltich, Maurer, and Nigg (2015) found that the increase in impact forces occurs due to increased joint stiffness, and as midsole hardness decreases, joint stiffness increases (2). However, in a previous study by Bishop and colleagues, there was no statistically significant difference in joint stiffness between shoes of varying cushioning properties (4). Despite differing study results regarding soft shoes or surfaces, a link between vertical impact loading and tibial shock injuries exists and can lead to further musculoskeletal injuries in runners, such as stress fractures (21).

Despite the many technological advancements in the running shoe industry, such as more cushioning and motion control built into shoes, the incidence of injuries has remained high for decades (29). A rear foot strike (RFS) has been attributed to higher GRF (29), and HCS tend to promote an RFS in runners. Additionally, the high cushion in rocker shoes makes proprioception difficult, and can lead to weakened ankles and arches over time, causing more injuries (50). What manufacturers believe is helping runners may be increasing injury risk over time. Thus, research is necessary to determine whether there may be advantages to using different types of shoes, especially with varying levels of cushioning.

Kinematics of Running

To fully understand how both injuries and shoes of varying cushioning affect running, one must be familiar with the kinematics of running. The gait cycle is composed of the events that occur during walking and running and is assessed from the initial contact of one foot with a surface to the following initial contact of that same foot (42). The gait cycle comprises two phases: stance and swing. Stance is when the foot comes in contact with the surface and swing is when a limb swings forward and leaves contact with the surface after foot plant, not only preparing the foot for heel strike (i.e., another surface contact) but also elevating the foot above the contact surface (42). Five specific events take place during the stance phase of a foot strike: heel-strike (HS), foot flat (FF), mid-stance (MS), heel-rise (HR), and toe-off (TO) (42). These will vary depending on the foot strike utilized and possibly by shoe type worn (e.g., minimalist vs. HCS vs. zero drop).

The patterns and impact forces occurring when someone is running depend on the way the foot initially makes contact with the ground, which is via a forefoot strike (FFS), midfoot strike (MFS), or rear foot strike (RFS). A foot strike can be defined as the portion of the bottom of the foot that makes the initial contact on the running surface while the body is in locomotion. A FFS is when the first one-third of the foot, near the metatarsal heads, makes contact with the running surface; while a RFS consists of the back one-third, or heel, making first contact (18). A midfoot strike (MFS) is more of a flat foot landing, and is typically the middle one-third of the foot making the first contact, although it sometimes can be difficult to determine (18).

The majority of distance runners are classified as RFS runners, and it is estimated that about 70-80% utilize the RFS, with around 1% using a FFS (19). The percentage of RFS runners may be as high as 95%, as evidenced by another study that focused on analyzing runners in a non-race setting (37). A RFS pattern is known to cause a repeated impact transient of vertical GRF, which is described as a rapid collision force of 1.5-3 times the runner's body weight within the first 50 ms of the stance phase (29). A 2010 study by Lieberman and colleagues found that unshod runners, or those who run barefoot, that had a FFS did not have the impact transient that RFS runners did, including both those who wore shoes while running and those who did not (29).

Researchers in another study that compared experienced runners with different foot strikes found the FFS pattern reduced vertical and resulting loading rates by the body at a greater extent in minimalist shod runners than in traditional shod runners (38). In contrast to this, because runners who wear HCS tend to adopt a RFS, they are potentially increasing impact forces, which may lead to increased injury risk - especially when considering the possibility of increased joint stiffness rates in HCS. Still, shoe cushioning can have a variety of effects on runners besides increasing impact forces.

Acute Effects of Cushioning

In recent years, minimalist shoes have been successfully marketed and sold to millions of runners. However, the recent trend of highly cushioned shoes is increasing in popularity despite little evidence supporting manufacturers' claims. Notably, some researchers focusing on shoe cushioning have discredited their assertions (14, 26).

Although there are few studies that focus in particular on HCS, several researchers have recently presented on this topic at national conferences (39, 43) and their abstracts are cited throughout this section.

Despite the positive impacts of better health and well-being that running has on its participants, in general there is increased overuse injury risk due to increased vertical impact forces and loading rates occurring while one is running. Using running shoes that have a softer midsole results in higher leg stiffness when compared to barefoot running, which may lead to higher impact forces (2). These high impact forces, in turn, may lead to increased risk of injury over time. With most runners more than meeting the American College of Sports Medicine guidelines for physical activity of 150 minutes of moderate intensity aerobic exercise per week (15), they are exposed to a higher risk of repetitive micro-trauma type injuries, especially lower extremity overload.

Compared to both regular and minimalist running shoes, maximally cushioned shoes caused higher horizontal instability regarding medial-lateral peak force with increased variability at the anterior-posterior direction (56). Loading rates were increased as the level of shoe cushioning increased (20). With these excessive stresses applied to the lower extremities as a runner repetitiously strikes the ground, a high prevalence of injuries, such as stress fractures, may occur over time (17).

In a preliminary study, researchers recruited five males who wore HCS and underwent a treadmill analysis. They found vertical average loading rate (VALR) was higher in HCS than in SCS, and GRF were not lowered, which contradicts what many manufacturers tend to claim for HCS (23). Notably, with these high impact forces occurring long-term (i.e., months or years), possible increased risk and incidence of injury in runners becomes obvious, especially if choosing to utilize HCS.

Comparing ALR and ILR in SCS and HCS in overground trials before and after a 5 kilometer treadmill run in both SCS and HCS, Carter and colleagues (10) found significant differences between shoe types. Results indicated no shoe-time interactions but significant differences for ALR and ILR between shoe types. However, other researchers have completed studies yielding conflicting results. No difference in peak vertical GRF between an acute bout in SCS vs. HCS was found by Strang et al. (43). Aminaka and colleagues found no difference in loading rate between shoe types (1). Another study that compared shoes of varying midsole thicknesses yielded no difference in shoes for transient peak of vertical GRF and loading rate (5). In this aforementioned project, participants ran across imbedded force plates with the shoe midsoles ranging from 0 mm to 16 mm. In general, the results of the prior discussed investigations demonstrate inconsistent results; although some methods were similar, none followed the exact same protocol. Thus, standardized procedures used in future research may produce more even consensus.

Shoe stiffness also impacts joints and limbs. Investigators that compared two levels of cushioned shoes found less stiffness in the shoes led to more limb stiffness in comparison to barefoot running (4). Six men and three women were tested in a barefoot condition and in two shoe conditions (with varying midsole thicknesses) by hopping on and running over a force plate in the three conditions (4). The order of testing was randomized by a coin toss. In each condition, subjects hopped on a force plate for 3 bouts of 1 minute each, with 1 minute of rest between trials. They also ran at both 2.23 m/s and 3.58 m/s on a treadmill for three 30-second bouts separated by 1 minute of rest in each condition. The researchers found a statistically significant difference in leg stiffness between the more cushioned shoe and barefoot condition but found no differences between the cushioned and less-cushioned shoes (4). They concluded mechanical properties of shoe cushioning may not be a main source of change in kinematics during running (4).

To be clear, the studies discussed so far with varying results warrant further research in comparing SCS and HCS. For instance, researchers utilized varying protocols, which decreased validity across study procedures. Furthermore, runners may be unable to perceive if their shoes are increasing or decreasing impact forces while running, leading them to conclude *if the shoe fits, wear it.*

With anything a consumer purchases comes a perception of whether it will “work” or not. Previous studies have indicated that runners have difficulties determining if the shoes they wear are beneficial and safe. Even perceptually capable consumers have trouble identifying biomechanically safe shoes for themselves based on shoe hardness (16).

In a recent study by Dinato et al., researchers recruited twenty-two men who ran in four different types of shoes on asphalt and in a laboratory to determine ground reaction forces (14). Subjects also rated each shoe in 9 categories relating to comfort levels. Results concluded that a person cannot predict comfort based on impact and plantar pressure (14). In another study involving running on a treadmill and overground in three pairs of shoes with varying levels of shoe midsole hardness, impact forces were obtained and participants provided feedback on their perception of shoe cushioning in each footwear condition (20). Results indicated participants altered their loading pattern in the hard midsole shoe, resulting in lower impact forces (20). Conversely, when they perceived cushioning in their shoes to be low, higher impact forces resulted (20). These studies reinforce the need for continual research due to many consumers lacking the expertise to determine whether their shoes will assist in the prevention of injuries, especially with long term, repetitive usage of shoes.

Long Term Interventions with Highly Cushioned Shoes

Rockered shoes have properties similar to HCS, therefore research projects utilizing this type of shoe are included in the current review of literature. Rockered shoes are similar to HCS with a high level of cushioning in the midsole, along with a slightly curved bottom that allows for a "rocking" movement. Such shoe designs are used in clinical populations to assist with treatment of lower body musculoskeletal disorders. In short, their usage has been shown to improve clinical conditions (26, 50), discussed next.

Rockered shoes have been shown to reduce the plantar flexion moment significantly to assist patients with Achilles tendinopathy (50). Longer term interventions have also been conducted using rockered shoes in persons with chronic conditions (5, 46). Diabetics who have peripheral neuropathy have utilized them to improve symptoms (26). However, for general populations, the rounded bottom creates a less effective base for the shoe and generates more instability (26). No advantages existed when using rockered shoes over standard shoes. Furthermore, rockered shoes induce higher peak force and loading rate (46). Despite these findings, there remains little research on whether rockered shoes are beneficial for a healthy, active population of runners. HCS, possibly classified as meta-rockers (i.e., they have a rounded bottom and are classified as either early or late stage meta-rocker (22), may serve as a surrogate. If HCS mimic the design of rockered shoes, the less stable base may increase injury risk, such as at the ankle or knee due to lack of balance. More research is warranted in order to determine if long-term usage of HCS on running populations increases impact forces or induces muscular imbalances, leading to potential, greater injury risk.

Summary of Literature

Based on previous and current research, increasing the amount of cushioning in shoes has been found to increase ALR and IRL in acute bouts of activity/running (2, 20, 33). However, other researchers using different methods, such as overground force plates rather than treadmills, determined that there was no significant acute difference between shoe types in impact forces (1, 51). Long term studies are scarce, creating a need for more research in this area. Few studies have focused on a chronic intervention regarding the usage of HCS and its effects on force measurements besides rocker shoe usage on clinical populations. No studies have focused on long term usage of SCS runners switching to HCS. In the current study, we hypothesized a difference between shoe types at baseline would occur and that difference would continue after 4 weeks, based on literature already discussed in this review.

Therefore, the purpose of this study was to examine the effects of a 4-week HCS intervention on running-related impact forces in adult recreational runners. Four weeks of HCS usage would assist in the comparison of acute and long term usage of these shoes versus SCS, which has not been conducted by researchers in the past. Ultimately, with the current research and forthcoming projects, injury rates or the risk of injury can be added to the equation of what shoe type is best to reduce repetitive trauma tissue damage, among other variables.

CHAPTER III: SUMMARY AND CONCLUSIONS

Neither baseline testing nor a four-week intervention period resulted in significant differences between SCS and HCS in Pk 1, Pk 2, ALR, ILR, and CT. Yet, with a high dropout rate in the INV group (i.e., HCS runners) vs. CON (i.e., SCS runners) due to discomfort and bruising, caution is warranted when transitioning to HCS. Based on this occurrence, wearing HCS should be a gradual process (not unlike wearing or transitioning to any other shoe type), with rotation between SCS and HCS advised. However, injury rate was not tracked within this study and it remains unknown if HCS increase the risk of typical running complaints. Future research in this area should focus on longer term studies that track injury rate in HCS.

This study had numerous limitations. The duration of the intervention period was four weeks, which may have inhibited potential, long-term kinematic changes from occurring. Shoe drop height (i.e., heel to toe drop) in SCS was not standardized, and several participants from each group rotated SCS use. Recall, HCS use in the INV group was a majority of the week; thus, they still utilized varying SCS shoes for safely. Lastly, running speed was not standardized across runners because of imbedded force plate use vs. using an instrumented treadmill. Future researchers may want to consider these limitations and alter or avoid them in prospective, longitudinal studies.

To our knowledge, this study is the first of its kind to observe effects of HCS over a chronic, albeit semi-short period on shoe impact characteristics. More research is needed to determine if long-term usage (i.e., > 4-weeks) of HCS can alter impact forces. However, based on the current observations, no increase in impact forces was found in INV (i.e., runners wearing HCS for 4-weeks). Caution is warranted in altering shoe type (e.g., transitioning to minimalist or HCS from SCS), and rotation between current, habitually utilized shoes and new shoes is recommended until habituation to the newer shoe type is apparent.

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APPENDIX A

Informed Consent
Northern Michigan University
School of Health and Human Performance

We invite you to participate in a research study titled:

Change in Running Mechanics after Acclimation to Highly Cushioned Shoes

(1) The purpose of this study is to examine the effects of a four week highly cushioned shoe (HCS) intervention or habituation period on dynamic ground reaction forces, peak force, vertical instantaneous loading rate, vertical average loading rates, leg stiffness, and gait characteristics in adult recreational runners. The prior mentioned variables are collectively termed biomechanical assessments that help explain how forces are transmitted through the lower limb when running over ground and in two different shoe types.

(2) You are invited to be in this study if you meet the following criteria:
   a. are an experienced, recreational runner,
   b. trained consistently for 3-5 days per week over the past two months and at least 10 miles per week,
   c. are 18-60 years of age,
   d. have never trained in highly cushioned shoes or have not trained consistently in them,
   e. have no health conditions that would prevent you from participating in a running program,
   f. are free from lower body injuries and answer "NO" to all questions on the PAR-Q (a physical activity readiness questionnaire)

(3) This study will consist of continuing your routine running training program for four weeks of at least ten miles per week total and partly wearing highly cushioned shoes (HCS), bought for you by the study researchers; to mitigate the risk of an over-use injury, we suggest you wear your traditional cushioned shoes one or two times per week in addition to wearing HCS "most" of the time.

(4) You will be asked to document each training run in a specific log provided to you.

(5) Exercise Science Laboratory (PEIF 146) measures will be collected and include:
   a. a pre and post-test format,
   b. each lab visit (i.e., pre- and post-tests) averages about 60-min of your time

c. each visit to the lab you will run in standard cushioned shoes (SCS) AND highly cushioned shoes (HCS) multiple times (up to 10 times in each shoe) over force platforms imbedded in the ground; during the run trials you will wear:
    i. reflective markers stuck to your clothing or skin
    ii. an accelerometer on your lower leg to track the acceleration/movement of your lower limb/leg

(6) If you are eligible and agree to participate in this study, we can schedule an appointment to fill out paperwork and order the correct shoe size

(7) RISKS: As with any physical activity, there are risks. There is risk of injury during testing and training on roads and/or trails. However, the researchers will attempt to minimize risk by fully explaining testing procedures and suggesting various trail runs along with reminding individuals the risk for ankle, knee, or other injuries while run training. All in all, participants will be informed random and unintended injury is always a possibility during physical activity.

(8) BENEFITS: Participants will learn about how their body (e.g., lower limbs) adjusts to highly cushioned shoes over the period of run training prescribed in this study. They will learn about ground reaction forces, muscle activation, gait characteristics, and rate of force development in highly cushioned versus standard cushioned shoes. From this information, they will be better able to predict or avoid running injury and potentially have a clearer view of the type of shoe that works best for them.

(9) The information/data you provide will be kept confidential; however, Northern Michigan University Institutional Review Board (a committee that reviews and approves research studies here on campus) and federal regulating agencies may inspect and duplicate records relating to this research. Identification numbers will keep your measurements and questionnaires anonymous. The results of this study may be published for scientific purposes, but your identity will not be revealed.

(10) Please read the entire informed consent. If you agree to be a participant in this study, please sign the informed consent on the appropriate lines. Do not sign and date until you are sure you understand the study and the study procedures and are sure you would like to participate. If you have any questions, please ask prior to signing.

(11) There is no financial cost for being in this research study and no monetary compensation will be given. However, you will be allowed to keep the highly cushioned shoes that you will wear during the study.

(12) Participating in this research study is completely voluntary. You may drop out at any time, for any reason, without repercussion.

If you have any questions concerning your rights as a participant in a research project you can contact Derek Anderson, chair of the Human Subjects Research Review Committee of Northern Michigan University (906-227-1873) or by email at dereande@nmu.edu. Any questions you have regarding this research project can be answered by the principal researcher who can be contacted via email at jcoullar@nmu.edu or phone (906-440-8677). Also, you can contact Dr. Scott Drum, thesis adviser, at sdrum@nmu.edu; 970-371-2620.

I have read the above informed consent. The nature, risks, demands, and benefits of the project have been described to me. I understand that I may ask questions and that I am free to leave the project at any time without any repercussions. I also understand that this informed consent document will be kept separated from the data collected in this research project to maintain confidentiality. Only the principle investigators will have access to this document.

______________________	______________________	___________
Name (Please Print)	Signature	Date

Thank you for agreeing to participate in this study.
Sincerely,

Jessica Corkin
Graduate Student
Exercise Science
School of Health and Human Performance
Northern Michigan University
jcoullar@nmu.edu
(906-440-8677)

APPENDIX B

Par-Q Form

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____________________

SIGNATURE ____________________ DATE ____________________

SIGNATURE OF PARENT ____________________ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

 Supported by: Health Canada Santé Canada

continued on other side...

APPENDIX C

Daily Running Log

ID Number: ______________________________ Date:________________________________

Type of shoe (Standard or HCS): ______________________________

Running Log

Distance covered:_______________miles

Duration: ______hours_____min **Time at start of run________:_____**am/pm

Terrain (circle all that apply and indicate approximate percentage of run in each category):

Asphalt _____% Concrete_____% Trail_____%

Indoor track_____% Treadmill_____%

Weather-Related Data

Temperature: _____________ ^{o}F

Weather pattern:__________________________________

Possible Daily Discomfort(s) While Running (Circle all that apply for each category):

Before Run (all non-running time):

Foot Ankle Lower leg Upper leg Hip Lower back

Mid back Neck region Other (specify)_____________

During Run (how do you feel in listed body regions during and immediately after run):

Foot Ankle Lower leg Upper leg Hip Lower back

Mid back Neck region Other (specify)_____________

After Run (all non-running time):

Foot Ankle Lower leg Upper leg Hip Lower back

Mid back Neck region Other (specify)_____________

Session RPE (Scale of 6-20):_________

Session intensity (circle one): low moderate high

Appendix D

Running Questionnaire

Please complete the following form it its entirety and email to jcoullar@nmu.edu by Tuesday, October 4th at 5pm. Note, we are now trying to get a VERY complete injury and type of running shoe history on you. There are "four" parts to this survey and 3 pages. Thank you for taking the time to fill this out to the best of your knowledge, giving estimates of timeframes and other feedback per your best guess or approximation. Please let Jessica or Scott Drum (sdrum@nmu.edu) know if you have questions.

Part I Running-Related Injury History

1. Currently, how long have you been injury free? _________ (days, months, or years) (underline/highlight one of the choices)
2. Please list all running-related injuries that prevented you from running in the past, whether orthopedic/joint, muscular, tissue (tendon, ligament), or other. For EACH injury you report, fill in a-d. We provided, hopefully, plenty of repetition, below. If no injuries, skip to pg. 3.

    a. Date of injury__________________ (1)
    b. Injury and description ____
    c. Type of surgery (if applicable) ____
    d. Length of rehabilitation with physical therapists (if applicable) _______________

    a. Date of injury__________________(2)
    b. Injury and description ____
    c. Type of surgery (if applicable) ____
    d. of rehabilitation with physical therapists (if applicable) _____________________
    a. Date of injury__________________(3)
    b. Injury and description ____
    c. Type of surgery (if applicable) ____
    d. Length of rehabilitation with physical therapists (if applicable) ______________

    a. Date of injury__________________(4)
    b. Injury and description ____

c. Type of surgery (if applicable) ____

d. Length of rehabilitation with physical therapists (if applicable) _______________

a. Date of injury__________________(5)

b. Injury and description ____

c. Type of surgery (if applicable) ____

d. Length of rehabilitation with physical therapists (if applicable) _______________

a. Date of injury__________________(6)

b. Injury and description ____

c. Type of surgery (if applicable) ____

d. Length of rehabilitation with physical therapists (if applicable) _______________

a. Date of injury__________________(7)

b. Injury and description ____

c. Type of surgery (if applicable) ____

d. Length of rehabilitation with physical therapists (if applicable) _______________

Part II Current shoe type

1. Name brand of shoe_____________________________ (e.g., Nike, Adidas, Saucony, Brooks, etc.)

2. Name of shoe model________________________________ (Pegasus, Beast, etc.)

3. Is the shoe(s) listed above, by your knowledge: minimalist or standard cushioning (circle one);

Other type of cushioning? _________________________

Is it "zero drop" between the heel and toe? ________________________ yes or no (circle one)

4. Currently, to date, how long have you been wearing these shoes? _______________

Part III Shoe Usage

A. Do you alternate running shoes (i.e., rotate a few pairs of shoes from day to day, within a week's time)? Yes OR No (circle one)

If yes, list any additional shoes besides the one from #2

A. Name brand of shoe____________________________ (1)
B. Name of shoe model_________________________________
C. Category (underline/highlight one): minimalist standard other? ________________
D. How long have you been wearing/alternating shoes?_______________

A. Name brand of shoe____________________________(2)
B. Name of shoe_________________________________
C. Category (underline/highlight one): minimalist standard
D. How long have you been wearing these?_________________

Part IV Typical running surface

Which running surface, approximately, do you run on the most? Underline/highlight one:

Treadmill Road Trail Other (please list)______________

For each running surface, write the **average** percentage of time you spend on each in a week's time. If there is a category you use that is not listed, please list it in the "other" category and give the approximate percentage.

Treadmill________% Road_________% Trail_________% Other__________%

GREAT! Thank you for filling this out and emailing to Jessica Corkin, Exercise Science Graduate Student, at jcoullar@nmu.edu, by Tues, Oct. 4 at 5:00pm.