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The Effect of Foot Strike in Female Runners

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A Quantitative Study on the Association Between Foot Strike and Injury Incidence Among Female Recreational Runners Between the Ages of 18 and 25.

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Abstract

PURPOSE: The purpose of this study is to determine if heel and forefoot striking influence the amount and type of lower extremity injuries in recreational female distance runners between the ages of 18 and 25. In addition to heel and forefoot striking, shoe type and training intensity were analyzed in relation to injury. **METHODS**: A quantitative, cross-sectional study was conducted anonymously utilizing The University of Akron's Qualtrics survey tool. The survey was adopted based on Goss and Gross (2012), in which the injury rate was assessed in both male and female runners with varying foot strikes. The survey was sent via email to members of the Zips Running Club, as well as other female recreational runners who fit the criteria to participate in the study. The survey asked general questions related to body composition, profession, shoe type, and foot strike pattern. Additional questions prompted participants for information related to changes in foot-strike pattern, injuries and other running questions. Different sections of questions assessed demographics, foot strike patterns, and injuries. **RESULTS**: Although the greatest percentage (75%) of injuries occurred in those respondents who utilized a heel strike pattern, there was a non-significant p-value of 0.68 . About 46.67% of those who utilize stability shoes and 66.67% of respondents who utilized a cushioned shoe reported running related injuries. Insufficient data was collected on shoe type and therefore, no conclusion was made. The p-value describing the relationship between shoe type and injury was 0.66, which is greater than 0.05, so the results are not significant. Due to a limited amount of responses, a conclusion could not be made in regard to training intensity and injury. The p-value describing the relationship between training intensity and injury was 0.76, which is greater than 0.05, so the results are not significant.

CONCLUSIONS: Although the results were not statistically significant, trends could be shown in data that related heel striking to injury. These results, although not statistically significant

could benefit runners, coaches, and health professionals as they determine whether a change in foot strike may help to prevent injury. With a larger sample size and a more accurate data collection method, this study could be improved to obtain statistically significant results.

Introduction

Foot-strike pattern has been a significant area of focus in the running community. The main types of foot-strike assessed in this study are heel strike, mid-foot strike, and forefoot strike. Those with a heel strike form make contact with the ground with their heel first while running, while those with a forefoot strike make contact with the ground with their forefoot first while running. Mid-foot runners strike the ground with the middle of the foot. While most runners utilize a heel strike, studies have shown that there may be an advantage to forefoot striking in the form of injury prevention. A study by Daoud, Geissler, Saretsky, Daoud, and Liberman (2011) describes how a runner who is a heel-striker extends their knee greatly on impact, while dorsiflexing their ankle, while a forefoot striker flexes the knee upon impact, while plantar flexing the ankle. Heel strikers' use of these knee extensors causes increased pressure on various ligaments in the lower extremities, potentially leading to injury. Furthermore, it is important to note that shoe type plays an important role in footstrike. Commonly, traditional running shoes are associated with heel striking, while minimalist shoes are associated with a forefoot strike (Goss et al., 2015). In addition, it is important to note that training intensity and weekly mileage may play a role in injury rate among female recreational runners. While the primary focus of this study is foot strike and injury rate, shoe type and training intensity/mileage will also be assessed in regard to injury rate.

A variety of methods have been used to analyze the foot strike patterns in runners. In a study done by Kernozek, Vannatta, Gheidi, Kraus, and Aminaka (2015), a pressure sensor on a track was used to determine which area of the foot contacted the ground first. Cameras were used to analyze motion and strike pattern in a study done by Goss et al. (2015). Lastly, in another study done by Goss, Lewek, Yu, and Gross (2015), a survey was given to runners that asked for

information regarding foot strike pattern, training, and shoe type. This study will examine the relationship between foot strike and injury through an anonymous survey.

While many studies have analyzed the relationship between foot strike pattern and injury, there has not been little attention or focus on foot strike in female runners. Female distance runners experience a higher rate of injury than male distance runners (Wunderlich, Griffin, & Wickham, 2008). This is due to a variety of factors, including amenorrhea and biomechanical differences, as discussed in the literature review (Hoguland, et al., 2015). Understanding why these injuries occur at a greater rate in females can help prevent these injuries. By determining the effect of foot strike pattern in female distance runners, coaches and healthcare professionals can use this information to help athletes prevent injury. The purpose of this study was to determine if heel and forefoot striking influence the amount and type of lower extremity injuries in recreational female distance runners between the ages of 18 and 25. The age group for this study was chosen to because this is a common age group for female recreational runners. Furthermore, this age group was chosen for ease of access by surveying members of the Zips Running Club.

To conduct this quantitative, cross-sectional study, an anonymous survey was utilized through The University of Akron's Qualtrics survey tool. The survey was adopted based on Goss and Gross (2012), in which the injury rate was assessed in both male and female runners with varying foot strikes.

Goss and Gross (2012) surveyed 904 male and female runners about various topics, including foot strike, shoe type, weekly mileage, and injury rate. The participants in the study were of varying ages. The study found that runners wearing a traditional type of shoe, which is more commonly associated with heel-striking, were 3.41 times more likely to sustain an injury

that those runners who wear minimalist shoes (2012). More specifically, those utilizing a traditional shoe were 2.64 times more likely to have a foot injury and 2.84 times more likely to sustain an ankle injury (2012). They were also 3.2 times more likely to sustain lower leg and knee injuries and 9.8 times more likely to sustain a hip injury (2012). Furthermore, when comparing foot strike to injury rate, Goss and Gross found that the injury rate in heel strikers was 52.4%, while forefoot strikers had an injury rate of 22.8%. There was no significant difference in injury rate found between low and high mileage groups (2012).

The survey for this study was sent via email to members of the Zips Running Club, as well as other female recreational runners who fit the criteria to participate in the study. The survey asked general questions related to body composition, profession, shoe type, and foot strike pattern. Additional questions prompted participants for information related to changes in foot-strike pattern, injuries and other running questions. The survey asked questions about height and weight, profession, shoe type, and foot strike pattern. In addition, the survey questions if participants had changed their foot-strike pattern and the reasoning behind the change, as well as any injuries they have previously experienced or reported had. There were 40 respondents to the survey. Two of the respondents' answers were discarded, as they did not meet the criteria to participate in the study.

The results of this study can be useful to runners, coaches, and health care professionals. The results and conclusions from this study can provide evidence in determining the relationship between foot strike pattern and injury rate. The data can help runners determine if a change in foot strike may be necessary to prevent future injuries and can assist them in determining their risk for lower extremity injury. For coaches and health care professionals, a better understanding of female running biomechanics can allow them to assist their clients/patients prevent injury.

Data from this study can promote future assessment of foot-strike and injuries specifically in the female population.

Three research questions were assessed in this study:

Research Question 1: Are heel strikers more likely to acquire injuries than forefoot strikers?

Research Question 2: Are those runners who wear traditional shoes more likely to become injured than those who wear minimalist shoes?

Research Question 3: Is more intense training associated with a higher injury rate? Intensity was determined by weekly running mileage.

Literature Review

Female running injuries

Studies have consistently shown that female distance runners have a higher injury rate than their male counter parts (Wunderlich, Griffin, & Wickham, 2008). It is important that exercise professionals and female runners themselves are aware of the common injuries that can occur and ways to prevent them in regard to nutrition, running form, and training.

Lower extremity injuries commonly seen in female athletes include anterior cruciate ligament tears, patellofemoral pain syndrome, ankle sprains, and stress fractures (Boles & Ferguson, 2010). While the cause of these injuries are not clear, differences in biomechanics and muscle weaknesses may be the cause.

Perhaps the biggest area of concern for female distance runners is stress fractures. Shimpei, Keishoku, Atsushi, Kenta, and Natsue (2017) assert that female distance runners have the highest rate of stress fractures than any other group in any other sport. A stress fracture occurs when there is repeated stress from activities such as running that leads to a small break in the bone, which, if left untreated, can lead to a full fracture (Shimpei et al., 2017). Lower extremity stress fractures can be found more commonly in females, with plantar loading caused by rear foot striking being a potential risk factor for stress fractures in the foot (Kernozek et al., 2015). Hoguland, Silbernagel, and Taweel (2015) state that the biggest two risk for stress fractures are a previous history of stress fractures and being female. Further risks include amenorrhea and reduced caloric intake, which are both prevalent in female endurance athletes with eating disorders or disordered eating patterns (Hoguland, et al., 2015). Amenorrhea can cause a decrease in bone density, leading to stress fractures.

Additionally, females also have a higher risk for having patellofemoral pain syndrome, or runner's knee. Approximately 13% of females between the ages of 18 and 25 have experienced patellofemoral pain syndrome (Willson, Sharpee, Meardon, and Kernozek, 2014). Also, the condition is the most common orthopedic condition for which runners seek care (Willson, et al., 2014). In the study done by Willson et al. (2014), found that females who decrease stride length had 31% decrease in patellofemoral stress.

Foot strike

The three main types of foot strike are heel strike, mid-foot strike, and forefoot strike. Several studies have shown forefoot striking to be correlated with injury prevention, causing many competitive runners to switch to a forefoot strike for injury prevention. A forefoot strike occurs when the ball of a runner's foot hits the ground first, while a heel strike is one in which a runner's heel hits the ground first (Daoud et al., 2011). Heel striking is much more common, with 75% of runners being heel-strikers (2015). Mid-foot strikers land "flat-footed", as compared to landing on the heel or ball of the foot (Giandolini et al., 2013). A runner who is a heel-striker extends their knee greatly on impact, while dorsiflexing their ankle. On the other hand, a forefoot striker flexes the knee upon impact, while plantarflexing the ankle (Daoud et al., 2011).

Since heel-strikers use their knee extensors more during initial impact, there is an increase in pressure on the patellofemoral ligament and tibiofemoral joint, leading to knee injuries and pain (Goss & Gross, 2012). Additionally, runners who strike with their heel have a greater peak in their ground reaction force than those who heel strike, which causes a greater load on the body of heel-strikers (Daoud et al., 2011). It has been suggested that this greater

force creates a shockwave that travels up the body, placing stress on the body's tissues (Daoud et al., 2011).

A study done by Kulmala, Avela, Pasanen, and Pakkari (2013) concluded that forefoot runners experience less force on the patellofemoral ligament and less movement of the knee frontal plane. Additionally, even mid-foot striking has been shown to help prevent injury. In a study done by Giandolini et al. (2013), runners who changed to a mid-foot strike had a ~30 % decrease in shock magnitude on the heel. Because of this information, a multitude of studies have been completed to assess the impact of forefoot, mid-foot, and heel striking on injury incidence.

In a study done by Vannatta, Kernozekb, and Gheidic (2017), researchers attempted to discover changes in gluteal muscle force when female heel-strikers changed to forefoot striking. Although gluteus maximus force increased, both maximal gluteus medius and minimus forces decreased. Furthermore, when the runners switched to a forefoot running pattern, there was a decrease in maximal hip internal rotation and adduction angles (Vannatta et al., 2017). These findings could indicate that it may be beneficial for female runners to change from a heel strike to a forefoot strike to prevent running related injuries.

Female running biomechanics

Significant biomechanical difference exists between males and females. As previously mentioned, female runners have a higher incidence of injury than male runners. The biomechanical factors present in female runners could be why there is a higher injury rate in female runners. These biomechanical variances include "different running kinematic waveform patterns and greater discrete joint angles" (Dean & Ishikawa, 2014). Furthermore, anatomical

variances, as well as ligament laxity and the female athlete triad put female runners at an even higher risk of injury (Dean & Ishikawa, 2014).

First, females have a different foot structure. Females have higher arches, shorter outside foot length, smaller instep circumference than their male counterparts (Wunderlich et al., 2008). In addition, females experience greater loads under the hallux and greater rearfoot contact times than males (Wunderlich et al. 2008).

In addition, a study done by Sakaguchi et al. (2014), found that in comparison to males, females have significantly greater peak knee abduction and hip abduction and internal rotation. It was also determined that females do not evert their heel as greatly as men (Sakaguchi et al, 2014). The findings suggest that because females have greater knee abduction, they have greater hip abduction and compensate by everting their heel (Sakaguchi et a., 2014).

Furthermore, a study done by Nadler et al. (2000), found that female athletes who reported lower extremity injuries had a difference of hip extensor strength between the left and right sides of approximately 10.9%. In female athletes who reported lower back pain, there was a 15% strength difference between left and right hip extensors (Nadler et al., 2000). In comparison, there was no significant difference between hip extensor strength between left and right sides for males for either of these conditions (Nadler et al., 2000)

Shoe style

In recent years, barefoot running and minimalist shoes have become increasingly popular, as compared to traditionalist or cushioned shoes. Many have suggested that switching to barefoot running or minimalist shoes can potentially prevent injury, while others assert that traditional shoes help a runner to avoid injury. Traditional shoes have a padded, elevated heel and absorb

shock, while minimalist shoes are more flexible, mimicking a barefoot running pattern, while providing protection against terrain and the elements (Ridge et al., 2015).

Barefoot and minimalist shoes have been associated with forefoot strike. Goss and Gross (2012), assert that barefoot running have increased knee flexion, experience decrease ground force, have a shorter stride length, and have an increase stride frequency. Traditionalist and cushioned shoes have been associated with a heel strike. Those who wear these type of shoes have a dorsiflexed ankle and extended knee (Goss & Gross, 2012).

In the study done by Goss and Gross (2012), those runners wearing traditional shoes were 3.41 times more likely to have had a running-related injury than those who ran barefoot or wore minimalist shoes. Furthermore, runners who wore traditional shoes were 2.64 times more likely to have had a foot injury and 2.84 times more likely to have had an ankle injury than those in minimalist shoes. They were also 3.2 times more likely to have had a lower leg or knee injury and 9.8 times more likely to have reported a hip injury (Goss and Gross, 2012).

To further support the effectiveness of barefoot running, a study done by Baltich and Boyer (2014), analyzed the biomechanics of female high school runners while barefoot running. Researchers discovered that when running barefoot, the runners experience a shorter stride length, a decreased knee flexion angle, and a decrease sole angle when their foot hit the ground (Baltich and Boyer, 2014). These changes in biomechanics could help to prevent injury.

On the other hand, Giuliani, Masini, Alitz, and Owens (2011), assert that barefoot and minimalist running can lead to injury. They did a case study on a 19-year-old runner, as well as a 35-year-old ultramarathoner, both who experienced cases of metatarsal stress fractures. It was found that the only recent change they had made to their training was switching to minimalist shoes that mimicked barefoot running (Giuliani et al., 2011). The researchers caution that

switching to minimalist footwear or barefoot running, does not guarantee that a change in foot strike will occur and that runners may need to alter their foot strike before making the transition (Giuliani et al., 2011).

Minimalist footwear may also provide benefits in running speed and economy due to their light weight and flexibility. In a study done by Ridge et al. (2015), it was found that those who switched from traditional to minimalist footwear had a 6.15% increase in running economy. The benefits of minimalist footwear may be both injury prevention and improvements in speed and efficiency.

Self -reported running

The accuracy of self-reported running is debatable. While surveying runners is an easy and effective way to gather information from a large group of people, many runners may not be able to accurately report information.

When Goss and Gross (2012), conducted data on foot strike, shoe type, and injury rate they chose to utilize a survey because of the ease of data collection. Instead of using medical records, they chose to utilize self-reported medical information because many runners will not seek medical attention for minor injuries. The researchers assert that the accuracy of self-reported foot strike is not well known.

In a study done by Bade, Aaron, and McPoil (2016), researchers asked runners to self-report their foot strike. Then, the runners were filmed while running to analyze their actual foot strike. It was found that cross country runners could correctly report their foot strike 56.5% of the time, while recreational runners could only correctly report their foot strike 43.5% of the time (Bade et al., 2016). Moreover, a study done by Goss et al. (2015), also found that many runners

could not correctly identify their foot strike. They also used video assessment to correctly identify foot strike pattern and found that only 68.3% of runners could correctly identify their foot strike.

In regard to running distance, a study done by Dideriksen, Soegaard, and Nielsen (2016), compared reported running distance to actual running distance tracked by a GPS. Researchers found no significant difference in reported distance versus actual distance run. Self-reported running may be more useful in analyzing distance run rather than more complicated concepts, such as foot strike.

Methods

` A cross-sectional survey was distributed to participants and data was analyzed quantitatively. The purpose of this study was to determine if heel and forefoot striking influence on the amount and type of lower extremity injuries in recreational female distance runners between the ages of 18 and 25. Participants were asked to anonymously complete a survey sent via email. The design of the survey was based on a survey by Goss and Gross (2012). The survey was created using The University of Akron's Qualtrics software. The original survey asked both male and female runners details about lower extremity injury rates and foot strike. The survey was revised for this study and focused only on female recreational runners between the ages of 18 and 25. The study was approved by The University of Akron's Institutional Review Board.

When the survey link was sent to participants, an informed consent was included at the beginning of the survey. This is informed consent explained the purpose of the study and a summary of what the participant would be asked to do. The informed consent stated that the participant will implied their consent by completing the survey. The link was sent to those via email who are members of the Zips Running Club, as well as other female recreational runners who are known to fit the criteria of being a female recreational runner between the ages of 18-25.

The survey consisted of 22 questions and took participants approximately ten minutes to complete. Participants were asked to report their foot strike, training intensity, shoe type, and the various injuries they have had. When reporting injuries, participants reported the area of injury as well as the injury type. Questions asked included: "How many years have you been running regularly?", "How often do you compete in races?", "What type of shoes do you commonly wear

when you run", and when you run distance greater than one mile, which statement best describes your foot strike tendencies?" All survey questions are included in Appendix A.

Results were gathered by comparing the percentage of injury in those who utilize a forefoot strike compared to those who use a heel strike and by using chi-square analysis. Further variables such as shoe type and training intensity were analyzed along with foot strike, also by comparing percentages and using chi-square analysis.

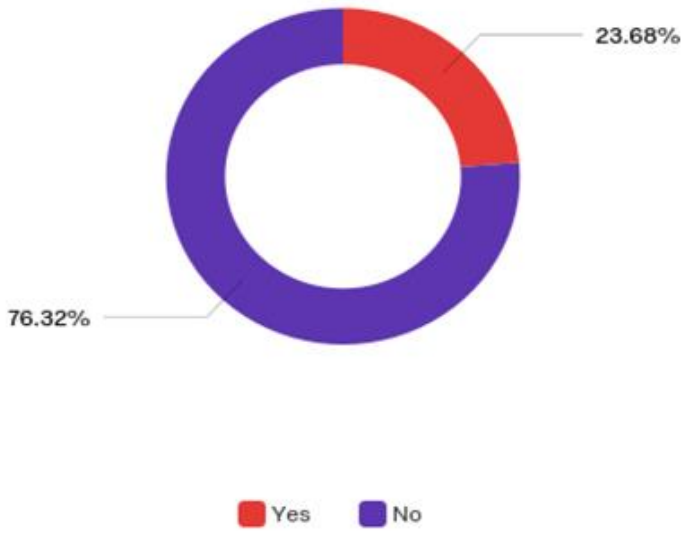
Results

There were 40 total respondents to the survey. Two of the respondents did not fit the inclusion criteria for the study so those results were discarded, leaving 38 total respondents. The purpose of the study was to identify if a link exists between foot strike and lower extremity injuries, in addition to analyzing shoe type and training intensity. While analyzing data, it is important to consider the demographics of the population. In this study, female recreational runners between the ages of 18 and 25 were surveyed, but it is important to note that participants have varying occupations, training habits, and body mass index numbers. The average BMI was a 23.1 kg/m^2 with the maximal BMI reported as a 45.6 kg/m^2 and a minimum of a 17.6 kg/m^2 . The median BMI was 22.1 kg/m^2 and the standard deviation was 4.78.

Approximately 76.32% of respondents said that they do not have an occupation that puts stress on the lower extremities, while 23.68% of respondents do have an occupation that requires much weight bearing. For those who did have professions that require being on their feet most of the day, they specified occupations such as a barista, a construction worker, a personal trainer, and a ski resort worker. **Figure 1** depicts the percentage of respondents who have an occupation that place stress on the lower extremities.

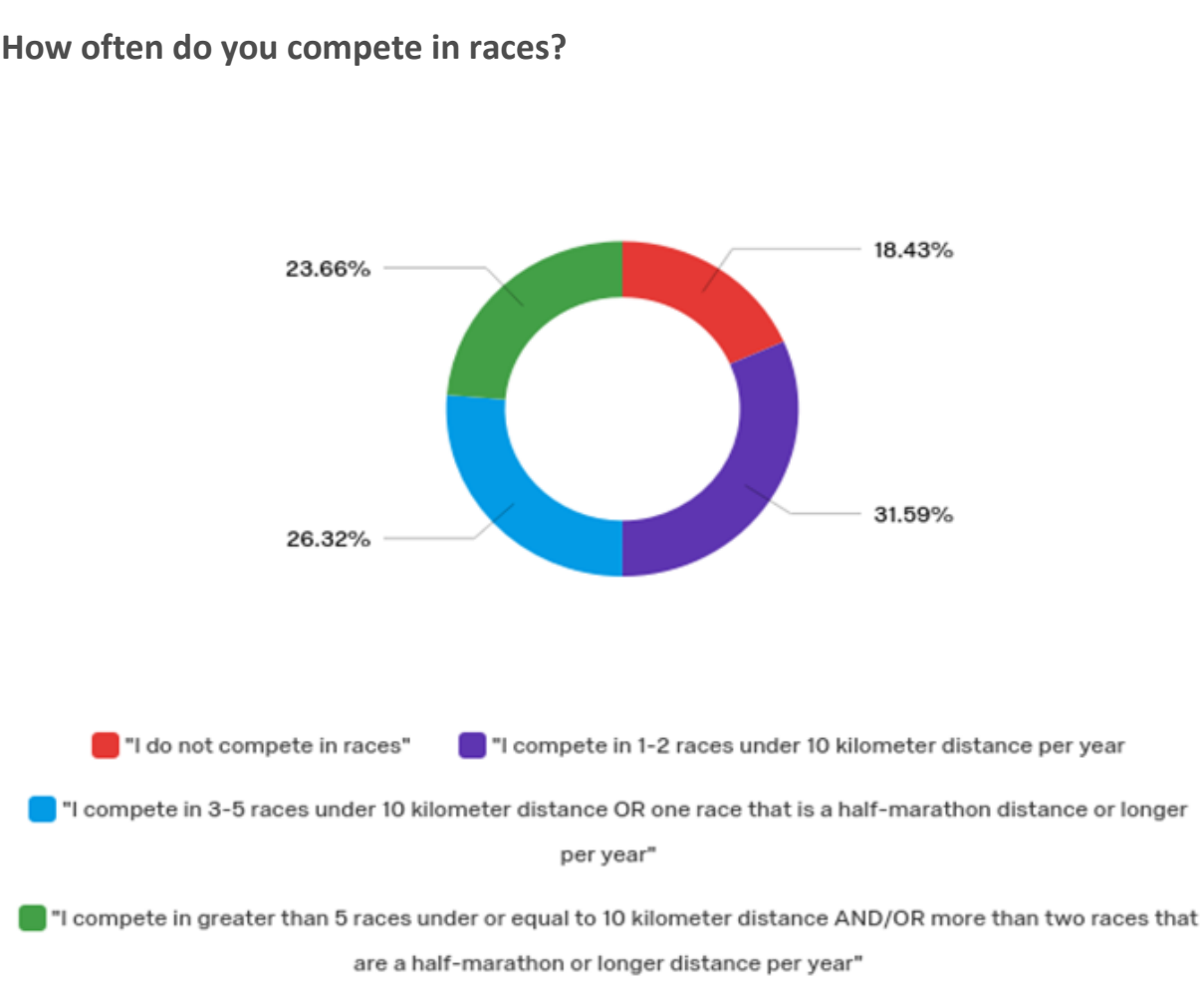
Figure 1: Weight-Bearing Occupations

Does your occupation and/or hobbies consist of physically demanding lower extremity weight bearing? (e.g. taking long walks, carrying heavy loads, etc...)



Most respondents, (71.05%) reported running regularly for 3 or more years, with only 13.16% running regularly for less than a year. Regarding training intensity, 60.58% of respondents reported running between 6 and 20 miles per week. Approximately 81.57% of respondents reported running a pace between 7 minutes per mile and 9 minutes per mile. In addition, 76.32% of respondents reported incorporating interval training into their training plans, with 44.71% of respondents doing multiple interval training sessions per week. Lastly, 81.58% of respondents reported running in races. **Figure 2** depicts the amount and type of races that respondents completed.

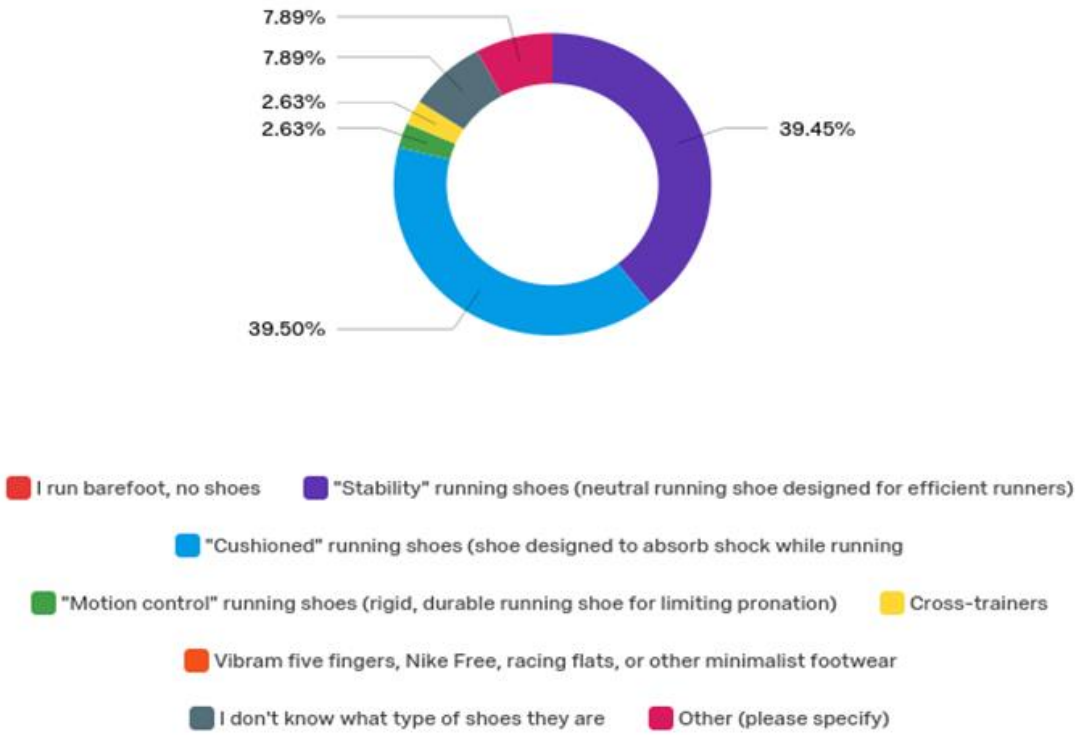
Figure 2: Running Race Distance and Frequency



Most respondents reported wearing stability or cushioned shoes, with 39.45% of runners wearing a stability shoes and 39.50% wearing a cushioned shoe. Approximately 65.79% of respondents wear the same shoes during every run, while 28.95% of respondents reported wearing different shoes for different runs, such as spikes during races and cushioned shoes during training runs. Furthermore, 71.05% of respondents have not changed their primary shoe type in the past two years. **Figure 3** shows the different type of shoes that respondents typically wear when running.

Figure 3: Types of Shoes

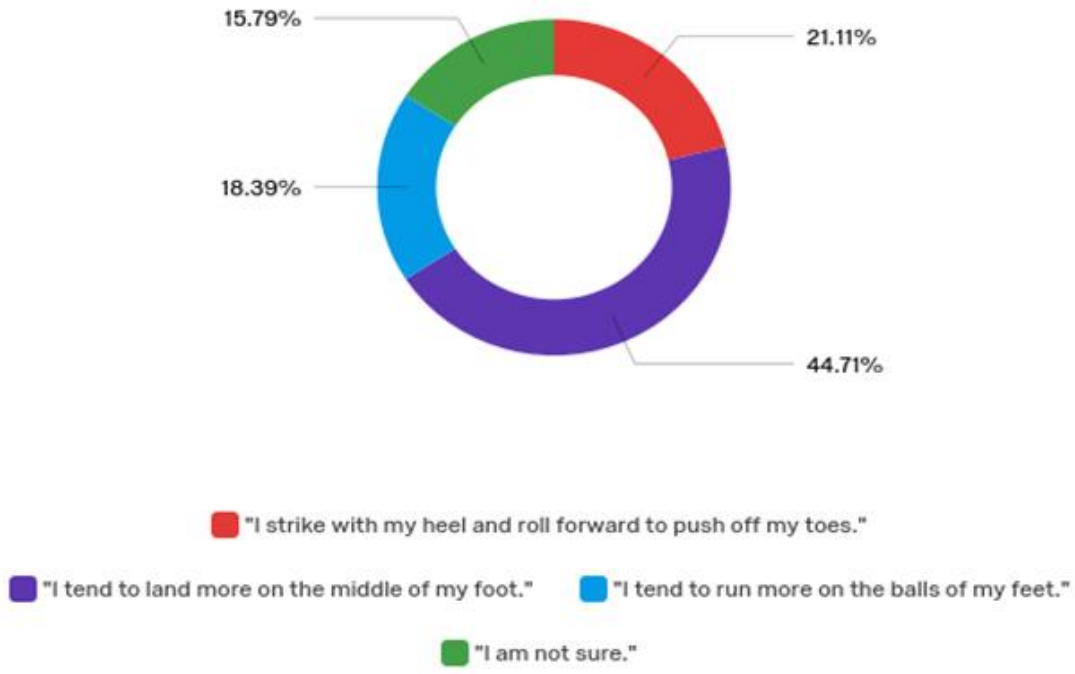
What type of shoes do you most commonly wear when you run (>50% of the time)?



A majority of respondents (44.71%) reported a mid-foot strike, with 21.11% reporting a heel-strike, and 18.39% of respondents reporting a forefoot strike. About 15.79% of respondents were not sure what their foot strike pattern is. Only 26.32% of respondents reported changing their foot strike pattern in the past two years, with 18.42% doing so because of injury. **Figure 4** shows the primary foot strike patterns of the respondents when they run distance greater than one mile.

Figure 4: Foot Strike Patterns

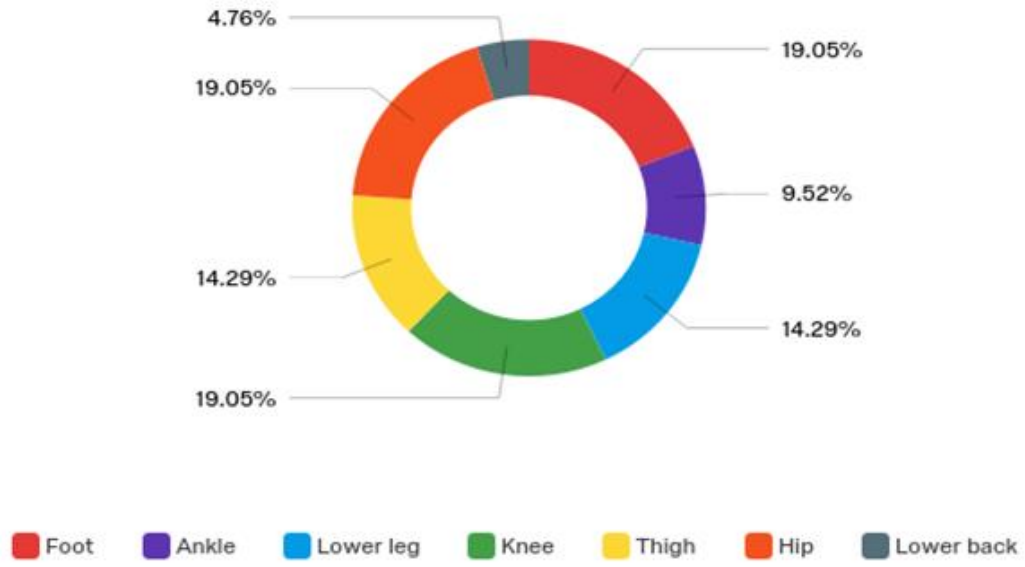
When you run distances greater than 1 mile, which statement best describes your primary foot strike pattern (>50% of the time)?



Approximately 19.05% of respondents who changed their foot strike pattern reported injuries in their knee, hip, and/or foot. About 14.29% of respondents who changed their foot strike pattern reported injuries in their thigh and/or lower leg. About 9.52% of respondents who changed their foot strike pattern reported injuries in their ankle and 4.76% reported injury to their lower back. **Figure 5** describes the injuries reported by those who changed their foot strike pattern due to injury.

Figure 5: Body Parts Involved in Running Injury Before Change in Foot Strike

If you changed your primary foot strike pattern due to an injury please select the body parts that were involved in the injury. An injury is defined as something that caused you to modify your training schedule for at least 1 week due to pain or discomfort with or without formal medical care.



Approximately 60.53% of respondents reported an injury in the past year that they believed was due to running. Approximately 24.27% and 24.24% of respondents who reported an injury reported injury in their lower leg and knee, respectively. Injury to the foot and hip were reported at a rate of 18.18% in respondents who reported injury. Of those who reported injury, 44.02% reported experiencing tibial stress syndrome and 19.22% reported stress fractures. In addition, 12.00% reported patellofemoral pain syndrome, and 8.00% reported tendinitis. Lastly, 12.00%

reported a sprain or strain. **Figure 6** reports injury location for those who reported having a running injury. **Figure 7** shows type of injury reported by those who claimed to have a running injury.

Figure 6: Self-Reported Injury Location

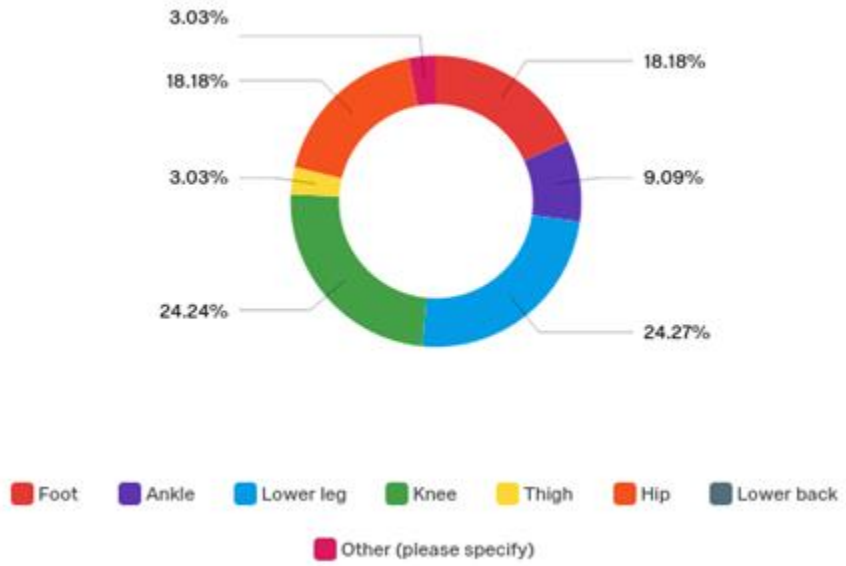
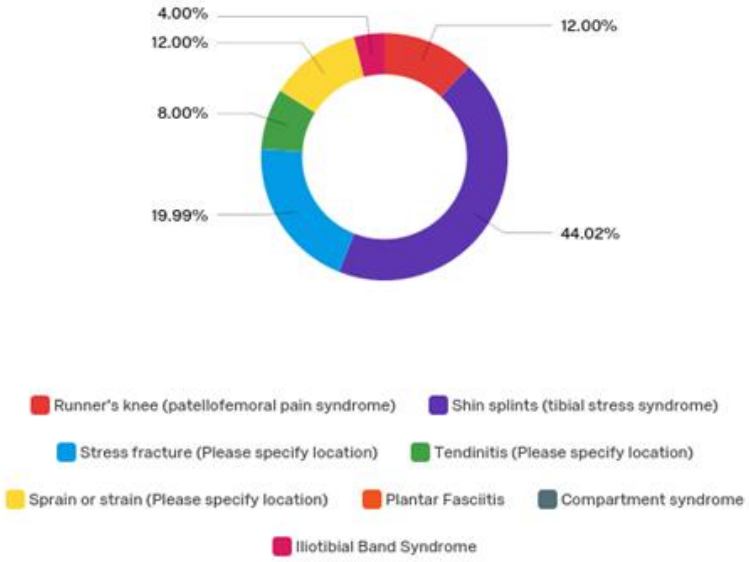


Figure 7: Self-Reported Injury Type



To answer research question #1, approximately 75.00% of heel strikers reported a running injury, while 58.82% of mid-foot strikers reported a running-related injury, while 71.42% of respondents with a forefoot striker reported a running related injury. Although the greatest percentage of injuries occurred in those respondents who utilized a heel strike, the p-value was greater than 0.05 at a 0.68, which means that the results are not significant. **Table 1** is a cross tabulation of foot strike and reported running injury.

Table 1: Cross tabulation of footstrike and reported running injury. The p-value was 0.68, which is greater than 0.05, so the results are not significant.

		Foot Strike			
		Heel Strike	Mid-Foot Strike	Forefoot Strike	Total
Reported Running Injury	Yes	6	10	5	21
	No	2	7	2	11
	Total	8	17	7	32

		Foot Strike
Reported Running Injury	Chi Square	0.76*
	Degrees of Freedom	2
	p-value	0.68

**Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.*

To determine if there was a correlation between foot strike and certain injuries, a cross tabulation was done between foot strike and injury type. Although 50% of the tibial stress syndrome cases reported were from heel-strikers, the p-value was 0.72, which is greater than 0.05, so the results, as seen in **Table 2**, are not significant.

Table 2: Cross tabulation between foot strike and injury type. The p-value was 0.72, which is greater than 0.05, so the results are not significant.

		Foot Strike			
		Heel Strike	Mid-Foot Strike	Forefoot Strike	Total
Injury Type	Runner's knee (patellofemoral pain syndrome)	0	2	1	3
	Shin splints (tibial stress syndrome)	5	2	3	10
	Stress fracture (Please specify location)	0	4	1	5
	Tendinitis (Please specify location)	0	1	1	2
	Sprain or strain (Please specify location)	1	2	0	3
	Plantar Fasciitis	0	0	0	0
	Compartment syndrome	0	0	0	0
	Iliotibial Band Syndrome	0	1	0	1
	Total	6	12	6	24

		Foot Strike
Injury Type	Chi Square	10.60*
	Degrees of Freedom	14
	p-value	0.72

**Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.*

To answer research question #2 to determine if there was a correlation between shoe type and injury, a cross tabulation was done between shoe type and injury presence. Although 46.67% of those who utilize stability shoes and 66.67% of respondents who utilized a cushioned shoe reported running related injuries, there was not enough data on other shoe types to come to a conclusion. The p-value was 0.66, which is greater than 0.05, so the results are not significant.

Table 3: Cross tabulation between shoe type and reported running injury. The p-value was 0.66, which is greater than 0.05, so the results are not significant.

		Shoe Type						
		I run barefoot, no shoes	"Stability" running shoes (neutral running shoe designed for efficient runners)	"Cushioned" running shoes (shoe designed to absorb shock while running	"Motion control" running shoes (rigid, durable running shoe for limiting pronation)	Cross-trainers	Vibram five fingers, Nike Free, racing flats, or other minimalist footwear	Total
Reported Running Injury	Yes	0	7	10	1	0	0	18
	No	0	8	5	0	1	0	14
	Total	0	15	15	1	1	0	32

		Shoe Type
Reported Running Injury	Chi Square	3.28*
	Degrees of Freedom	5
	p-value	0.66

*Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.

In order to answer research questions #3 to see if there is a relationship between training intensity, a cross tabulation was done between weekly running miles and running related injuries. Each group, from low to high mileage had running related injuries. Due to a limited amount of responses, a conclusion could not be made. As seen in **Table 4**, the p-value was 0.76, which is greater than 0.05, so the results are not significant.

Table 4: Cross tabulation between weekly running mileage and reported running injury. The p-value was 0.76, which is greater than 0.05, so the results are not significant.

		Weekly running mileage					
		6-10 miles per week	11-20 miles per week	21-30 miles per week	31-40 miles per week	>40 miles per week	Total
Injury in the past year	Yes	8	5	4	3	3	23
	No	5	5	1	3	1	15
	Total	13	10	5	6	4	38

		Weekly running mileage
Injury in the past year	Chi Square	1.89*
	Degrees of Freedom	4
	p-value	0.76

*Note: The Chi-Square approximation may be inaccurate - expected frequency less than 5.

In summary, the following research questions were answered.

Research Question 1: Are heel strikers more likely to acquire injuries than forefoot strikers?

Most respondents (44.71%) reported a mid-foot strike, with 21.11% reporting a heel-strike, and 18.39% of respondents reporting a forefoot strike. Approximately 15.79% of respondents were not sure what their foot strike pattern is. About 75.00% of heel strikers self-reported having a running injury, while 58.82% of mid-foot strikers reported a running-related injury, and 71.42% of respondents with a forefoot striker reported a running related injury. The greatest percentage of injuries occurred in those respondents who utilized a heel strike, but the p-value the described the relationship between foot strike and injury was greater than 0.05 at a 0.68, which means that the results are not significant.

Research Question 2: Are those runners who wear traditional shoes more likely to become injured than those who wear minimalist shoes?

Even though 6.67% of those who utilize stability shoes and 66.67% of respondents who utilized a cushioned shoe reported running related injuries, there was not enough data on other shoe types to come to a conclusion as to whether shoe type is related to injury. The p-value that described that relationship between shoe type and injury was 0.66, which is greater than 0.05, so the results are not significant.

Research Question 3: Is more intense training associated with a higher injury rate?

Each group, from low to high mileage, had running-related injuries. Due to a limited amount of responses, a conclusion could not be made. The p-value that described the relationship between mileage and injury was 0.76, which is greater than 0.05, so the results are not significant.

Discussion

The purpose of this study was to expand on the work done by Goss and Gross by narrowing the scope focusing solely on female recreational runners between the ages of 18 and 25. Through a survey, the main focus of this study was to determine if there was a relationship between foot strike and injury rate, as well as shoe type, which is often associated with foot strike. Furthermore, the relationship between training intensity and injury rate was assessed, as well.

In the study done by Goss and Gross (2012), runners utilizing a heel strike had an injury incidence of 52.4%, while midfoot strikers had an injury incidence of 34.7%, and forefoot strikers had an injury incidence of 22.8%. They found that runners who were traditional shoes were 3.41 times more likely to have an injury. Lastly, they found that there was no difference in injury incidence between those surveyed who ran high or low mileage (Goss and Gross, 2012).

The survey in this current study utilized many of the same questions as those asked by Goss and Gross (2012). The findings revealed a non-statistically significant relationship between foot strike and injury, as 75.00% of respondents who utilize a heel strike reported having a running related injury in the past year. In addition, although not statistically significant, the most cases of tibial stress syndrome, or shin splints, was reported by those respondents who reported a heel strike stance. This information may be useful to runners who experience tibial stress syndrome, to provide consideration for changing their foot strike to address injuries. The results of injury and shoe type revealed 44.67% using stability shoes and 66.67% reporting cushioned shoes. Due to low response rate, the findings were not significant but this information may support a relationship exists between show type and injury. Both shoe types are often worn by those who utilize a heel strike. A high percentage of injuries were seen in all mileage groups.

With more respondents, a more concrete conclusion could be made. Although, the results of this study are not statistically significant, the results may be useful to coaches, health care professionals, and runners. If a runner has a history of injury, foot strike can be analyzed to see if a change in foot strike may be beneficial to prevent future injury.

When evaluating data, it is important to recognize notable points and trends in the survey administered. The majority of respondents reported using a mid-foot strike. It has been shown that 75% of runners utilize a heel strike. However, due to self-report there may be inconsistencies with subjects incorrectly reporting foot strike pattern. (Kernozek et al., 2015). Errors with foot strike could be due to a lack of education about foot strike pattern. Furthermore, it is important to note that there were respondents who changed their foot strike pattern due to injury. Approximately 26.32% of respondents reported changing their foot strike pattern in the past two years, with 18.42% reporting that the change due to injury. Hip, knee, and foot injuries accounted for 19.05% each of those surveyed who changed their foot strike pattern. In addition, 14.29% of respondents who changed their foot strike pattern reported injuries in their thigh. Another 14.29% of respondents who changed their foot strike pattern reported injuries in their lower leg. Lastly, 9.52% of respondents who changed their foot strike pattern reported injuries in their ankle and 4.76% reported injury to their lower back. The fact that many of those surveyed who changed their foot strike pattern due to injury shows that it may be beneficial to change foot strike for injury prevention.

Many factors may influence the injury rates reported in the current study. Future studies should consider implementing a broader array of variables for relationships. Body composition would be an ideal variable to explore with reported injury. The relationship of low BMI and amenorrhea could lead to lower bone density and therefore, resulting in high injury rates. Higher

BMI may also lead to high injury rates due to increased pressure and load on the joints. Furthermore, with 23.68% of respondents having an occupation that requires significant weight bearing, it is important to note that that, in combination with running, could potentially cause injury. Additionally, factors such as how often shoes are changed and how often and how far a respondent races could have affected injury outcomes.

Limitations

There were several limitations to this study. Perhaps the largest limitation was the small sample. Only 40 people responded to the survey and the results for two respondents were eliminated for not meeting inclusion criteria to participate in the study, leaving 38 respondents. The small sample size was due to having a very narrow focus. Not only did participants have to be runners, but they had to be female within a certain age group. The small sample size limited the amount of data required for statistical power with analysis. Furthermore, there was not enough data reported on shoe type. In addition, there was insufficient data to analyze whether there was a relationship between weekly mileage and injury. In the future, this study could be improved by sending out the survey to more runners who meet the criteria or by changing the focus to a wider scope of participants.

Another limitation to this study was a lack of education about foot strike and the inaccuracy of self-reporting. Many recreational runners may not know what foot strike is and how to define the different types. Although this was addressed by describing the different types of foot strike in the survey, many still may not be able to accurately recall what their foot strike is. In the future, including pictures and diagrams with the survey could better help to explain foot strike. Future studies could also analyze foot strike with a camera, in addition to a survey to determine the accuracy of self-reporting.

Additionally, it is important to note that the study conducted by Goss and Gross (2012) had a large enough sample size to discard responses that may have been affected by additional variables. For instance, they discarded responses from those who had a profession that required them to be on their feet for most of the day. Furthermore, they discarded responses from individuals who recently changed their foot strike pattern or shoe type. This allowed the researchers to ensure that injuries were truly be analyzed in correlation foot strike and shoe type and that outside factors were not affecting the results. Again, with more respondents, it would be possible to make sure there were no outliers or external factors affecting the results.

Lastly, there was clearly a difference in training and speed between respondents. Some respondents ran at a pace greater than or equal to 10 minutes/mile, while others ran at a pace faster than a 7 minute/mile pace. Some respondents ran between 6 and 10 miles, while others ran over 40. Further, while many respondents, did race, some did not. While training intensity was analyzed, a lot of factors, such as racing and pace can affect intensity. To improve this study, runners on a similar training plan could be used as the sample group.

Personal Statement

Throughout the research done on this project, I have truly gained valuable knowledge that will help me upon entering graduate school to obtain my Doctor of Physical Therapy degree and in my future career. I learned much about the importance of foot strike and shoe type in relation to injury. This information can be valuable to my future patients who may be suffering lower extremity injuries from running. In addition, I learned how to create and distribute a survey and how to analyze data, as well as the importance of having data that is significant. I would like to thank my sponsor, Dr. Laura Richardson, for guiding me throughout this process and to my readers, Dr. Stacey Buser and Mrs. Melissa Smith for taking the time to assist me with this project. Lastly, I would like to thank the members of the Zips Running Club for allowing me to survey their members and The Williams Honors College for allowing me this opportunity to pursue research on a topic that is very important to me.

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Appendix A

Foot-Strike Pattern and Injury Survey

Q1 Are you a female runner (defined as running at least 3 days per week for a least 2 miles per run) between the ages of 18-25?

- Yes (1)
- No (2)

Q2 What is your height in inches?

_____

Q3 What is your weight in pounds?

_____

Q4 Does your occupation and/or hobbies consist of physically demanding lower extremity weight bearing? (e.g. taking long walks, carrying heavy loads, etc...)

- Yes (If so, please explain) (1) _____
- No (2)

Q5 How many years have you been running regularly (at least 3 times per week for 2 miles per run)?

- ○ less than 1 year (1)
- ○ 1-3 years (2)
- ○ 3+ years (3)

Q6 What is your average WEEKLY running mileage?

- ○ 6-10 miles per week (1)
- ○ 11-20 miles per week (2)
- ○ 21-30 miles per week (3)
- ○ 31-40 miles per week (4)
- ○ >40 miles per week (5)

Q7 What is your average training pace?

- ○ 10 min/mile) (1)
- ○ 6.1 - 7.0 miles per hour (approx 9 min / mile) (2)
- ○ 7.1 - 8.0 miles per hour (approx 8 min / mile) (3)
- ○ 8.1 - 9.0 miles per hour (approx 7 min / mile) (4)
- ○ > 9 miles per hour (< 7 min / mile) (5)

Q8 How often do you incorporate speed/interval runs into your training plan?

- "I do not incorporate speed/interval training into my training plan" (1)
- "I incorporate speed/interval training one day per week" (2)
- "I incorporate speed/interval training more than one day per week" (3)

Q9 How often do you compete in races?

- "I do not compete in races" (1)
- "I compete in 1-2 races under 10 kilometer distance per year (2)
- "I compete in 3-5 races under 10 kilometer distance OR one race that is a half-marathon distance or longer per year" (3)
- "I compete in greater than 5 races under or equal to 10 kilometer distance AND/OR more than two races that are a half-marathon or longer distance per year" (4)

Q10 What type of shoes do you most commonly wear when you run (>50% of the time)?

- ○ I run barefoot, no shoes (1)
- ○ "Stability" running shoes (neutral running shoe designed for efficient runners) (2)
- ○ "Cushioned" running shoes (shoe designed to absorb shock while running (3)
- ○ "Motion control" running shoes (rigid, durable running shoe for limiting pronation) (4)
- ○ Cross-trainers (5)
- ○ Vibram five fingers, Nike Free, racing flats, or other minimalist footwear (6)
- ○ I don't know what type of shoes they are (7)
- ○ Other (please specify) (8) _____

Q11 What statement best describes your running shoe selection tendencies?

- ○ "I wear the same shoe type for 100% of my running." (1)
- ○ "I vary the type of shoes I wear depending on the goals of the training session." (2)
- ○ "I sometimes wear shoes and sometimes run barefoot." (3)
- ○ "I don't know what type of shoes I wear." (4)
- ○ Other (please specify) (5) _____

Q12 Have you changed your primary SHOE TYPE (or started going barefoot) within the last 2 years?

- Yes (1)
- No (2)
- No (3)

Q13 How long have you been wearing that type of shoe (or running barefoot)?

- 1 month (1)
- 6 months (2)
- 1+ years (3)

Q14 How often do you replace your running shoes?

- Not applicable, barefoot runner (1)
- Less than 3 months (2)
- Every 3-6 months (3)
- Every 7-12 months (4)
- Greater than 12 months (5)

Q15 When you run distances greater than 1 mile, which statement best describes your primary foot strike pattern (>50% of the time)?

- "I strike with my heel and roll forward to push off my toes." (1)
- "I tend to land more on the middle of my foot." (2)
- "I tend to run more on the balls of my feet." (3)
- "I am not sure." (4)

Q16 When you run distances greater than 1 mile, which statement best describes your foot strike tendencies?

- "I use 1 foot strike pattern (from question 10) 100% of the time." (1)
- "I vary my foot strike pattern depending on the goals of the training session." (2)
- "I am not sure about my foot strike pattern tendencies." (3)

Q17 Have you changed your foot strike pattern within the last 2 years?

- Yes (1)
- No (2)

Q18 If you changed your foot strike in the last 2 years, why did you do so?

- ○ Injury (1)
- ○ Speed/efficiency (2)
- ○ Other (Please specify) (3) _____
- ○ "I have not changed my foot strike pattern in the last 2 years" (4)

Q19 If you changed your primary foot strike pattern due to an injury please select the body parts that were involved in the injury. An injury is defined as something that caused you to modify your training schedule for at least 1 week due to pain or discomfort with or without formal medical care.

- ☐ Foot (1)
- ☐ Ankle (2)
- ☐ Lower leg (3)
- ☐ Knee (4)
- ☐ Thigh (5)
- ☐ Hip (6)
- ☐ Lower back (7)
- ☐ I did not change my foot strike pattern due to injury. (8)

Q20 If an injury is defined as something that caused you to modify your training schedule for at least 1 week due to pain or discomfort (with or without formal medical care), have you experienced any lower extremity injuries IN THE PAST 12 MONTHS that you believe were caused by running?

- ○ Yes (1)
- ○ No (2)

Q21 If yes to questions 20, select the involved body part(s) involved:

- ☐ Foot (1)
- ☐ Ankle (2)
- ☐ Lower leg (3)
- ☐ Knee (4)
- ☐ Thigh (5)
- ☐ Hip (6)
- ☐ Lower back (7)
- ☐ Other (please specify) (8)
- ☐ I have not had a lower extremity injury in the past 12 months (9)

Q22 Please check all of the following lower extremity injuries you have had within the past 12 months that you believe were caused by running

- ○ Runner's knee (patellofemoral pain syndrome) (1)
- ○ Shin splints (tibial stress syndrome) (2)
- ○ Stress fracture (Please specify location) (3) _____
- ○ Tendinitis (Please specify location) (4) _____
- ○ Sprain or strain (Please specify location) (5) _____
- ○ Plantar Fasciitis (6)
- ○ Compartment syndrome (7)
- ○ Iliotibial Band Syndrome (8)