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Biomechanical Comparison of "Old" and "New" Cheer Shoes in Collegiate Cheerleaders

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BIOMECHANICAL COMPARISON OF “OLD” AND “NEW” CHEER SHOES IN COLLEGIATE CHEERLEADERS

by

ABIGAIL JOHNSON

(Under the Direction of Samuel J. Wilson)

ABSTRACT

INTRODUCTION: The sport of cheerleading requires that athletes perform with a high degree of flexibility, strength, endurance, and balance. The leading injury in cheerleading is a lateral, inversion, ankle sprain. As footwear serves as an interface between the foot and the surrounding environment, characteristics of shoes should be monitored to determine the effects on proprioceptive communication. No previous literature was found that examined the biomechanical differences between “Old” and “New” shoes in collegiate cheerleaders. PURPOSE: The purpose of this study was to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step-down, landing tasks in “old” and “new” cheer shoes. METHODS: Participants included 5 male and 20 female collegiate cheerleaders (19.88 ± 1.36 years; 61.94 ± 9.33 kg; 162.70 ± 6.68 cm). Sixteen anatomical retroreflective markers were placed on each participants’ lower extremities. Participants completed randomized trials of ten balance conditions as well as step-down tasks consisting of a leveled and a tilted platform. Data collected from two days of testing was used for analysis. RESULTS: Analyses revealed no statistical significance for postural sway measures between “Old” and “New” shoes ($p>.05$). Analyses revealed a statistically significant interaction between shoe and condition when examining the ankle joint angle during step-down tasks ($F(1,24)=12.070$, $p=.002$). Further investigation revealed main effects of both shoe ($F(1,24)=85.541$, $p<.001$) and condition ($F(1,24)=893.489$, $p<.001$) when examining ankle joint angular velocity during step-down tasks. CONCLUSION: “Old” shoes and tilted surfaces appear to display decrements in step-down, landing mechanics when compared to their counterparts. However, further investigation is needed to determine the effect of shoe age on the ability to maintain balance.

INDEX WORDS: Cheerleading, Footwear, Balance, Step-down tasks, Shoe age

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DEDICATION

This thesis is dedicated to my family. This journey was made all the more enjoyable because of your constant encouragement and support. Thank you for pushing me, reminding me, and holding me accountable. This accomplishment is just as much yours as it is mine. I love you all.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Page

CHAPTER 1: DEFENSE DOCUMENT

Introduction

The sport of cheerleading requires that athletes perform with a high degree of flexibility, strength, endurance, and balance. Contrary to the stigmas associated with cheerleading, previous research has shown that the fitness level of cheerleaders is like that of many other collegiate sports, such as gymnastics, soccer, tennis, and volleyball (Jacobson, Redus & Palmer, 2005; Jones & Khazzam, 2017). Similar to gymnastics, individuals who participate in cheerleading must be able to perform tumbling, jumping, stunting, and other acrobatic-like movements consistently. These types of sport-specific movements are only successfully completed with a focus on total body coordination, spatial awareness, postural control, and balance maintenance. For collegiate cheerleaders, these skills are practiced, on average, three days a week for three hours each session. The total time commitment accumulates to approximately 150 days of practice with additional weight training sessions, sideline sport cheering, appearances for the University, and performing at competitions (Jacobson, Redus, & Palmer 2005; Shields & Smith, 2006; Shields & Smith, 2011). Cheerleading participation is growing at a rate of 18% per year in the United States. Athletes start participating in cheerleading as young as the age of 5 and practice year around. (Shields & Smith, 2006; Shields & Smith, 2011; Shields, Fernandez & Smith, 2009).

Overall, in all age groups of cheerleading, the leading mechanism of injury is due to falls (29.4%). Sprains and strains are the most common types of injuries sustained, accounting for 53% of all injuries (Shields & Smith, 2006; Shields & Smith, 2011; Shields, Fernandez & Smith, 2009). Further, the most commonly injured joint is the ankle, accounting for 44.9% of all injuries. The ankle injuries specifically involve damage to the lateral ligaments and often occur with the ankle in a plantar-flexed position (Jacobson et al., 2004). To attenuate the large, rapid loads when landing from jumps and tumbling, along with dismounting from stunts, the ankle joint complex is in a supinated, inverted, plantarflexed and adducted position. The rapid and unexpected joint perturbations that can occur when landing in this position may generate large supination moments of the ankle complex that can result in damage to the lateral ankle ligaments (Shields & Smith, 2006; Simpson et al., 2018). An important contributor to fall risk is the control of posture. Postural control involves many different underlying physiological systems, such as visual acuity, somatosensory, and vestibular function. Alterations to any of these systems may result in balance decrements, and increased fall risk (Simpson, DeBusk, Hill, Knight & Chander, 2018; Wilson, Garner, & Loprinzi, 2016).

Because footwear serves as the interface between the human foot and the external environment, it plays a vital role in the maintenance of postural control and balance (Chander, Morris, Wilson, Garner, & Wade, 2016). Standard footwear characteristics that influence postural control are footwear mass, shaft height, outsole/midsole hardness, and heel height. Cheerleading specific footwear is designed to have a low mass, slip-resistant rubber outsoles, and EVA foam midsoles to provide cushioning and shock absorption. Previous research has shown that these characteristics influence subtalar joint adaptability, range of motion, and the capability for ground reaction force attenuation (Simpson, DeBusk, Hill, Knight & Chander, 2018). Furthermore, these design characteristics have been attributed to the reductions in postural stability and sensory feedback from cutaneous receptors of the foot and ankle (Simpson, DeBusk, Hill, Knight & Chander, 2018; Wu & Chiang, 2004). Cheerleading shoe design poses unique challenges as increased footwear mass and moment of inertia can affect athletes’ ability to perform tumbling, jumping, and stunting skills properly. Therein lies the difficulty of creating a shoe that is light weight, structurally sound, and durable for the wear and tear of sport-specific skills performed (Eckley, 2018). Although evidence regarding changes in the structural integrity of cheerleading specific shoes and how they affect lower extremity biomechanics is limited, decrements in postural control and lower extremity mechanics have been reported in other types of athletic footwear. Early work on footwear biomechanics suggests that runners should change their running shoes every 300-400 miles to accommodate for decreases of shock absorption properties (Kong, Candelaria & Smith, 2009). Researchers further reported that the main changes observed in response to the increased “mileage” or use of the running shoe are at the ankle (Aquino, Amasay, Shapiro, Kuo & Ambegaonkar, 2019; Kong, Candelaria & Smith, 2009; Nigg, Baltich, Hoerzer & Enders, 2015). More recent work examined the effects of “new” compared to “dead” pointe shoes in professional ballet dancers. There, it was observed that the “dead” pointe shoes decreased balance during ballet specific skills, as well as increased muscle activity of the lower extremities. These findings suggest that the wear and tear of the pointe shoes may increase lower extremity injury risk in dancers (Aquino, Amasay, Shapiro, Kuo & Ambegaonkar, 2019; Kong, Candelaria & Smith, 2009).

On average, collegiate cheerleaders will wear one pair of shoes for the entirety of a season, typically lasting from August to May or the length of the academic year. Additionally, cheerleaders may continue to wear a previous season’s shoes for practices the following year. To our knowledge, no research exists regarding the appropriate time to replace old shoes and begin wearing new cheer shoes. Additionally, limited information is available regarding the effects of cheerleading specific footwear, old or new on balance and lower extremity biomechanics during landing, or how continued “wear and tear” of cheer shoes may alter these effects. Researchers for this study hypothesized that balance performance would be decreased with “old” compared to “new” cheer shoes. Additionally, it was hypothesized that there would be greater risk of injury with “old” shoes than with “new” shoes when examining landing mechanics. Therefore, this study aimed to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step-down tasks in “old” and “new” cheer shoes.

Methods

Experimental Design

This study used a repeated measures, randomized design to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step-down tasks in “old” and “new” cheer shoes. Analyses conducted focused on how balance performance and landing mechanics differ between the two shoe types.

Participants

Participants for this study included 25 healthy male (n=5) and female (n=20) collegiate cheerleaders between the ages of 18 and 25 years. Additional inclusion criteria were possessing no cardiovascular, respiratory, neuromuscular, or musculoskeletal ailments. Individuals who participated in the study owned one pair of “old” shoes. A “new” pair, matching the size and style of the “old” pair, was provided to each individual during testing. “New” was defined as shoes that are taken directly out of the box to be used for testing. Each participant wore a pair of “new” shoes of the preferred size and style, meaning that each pair of shoes was only worn by one participant. “New” shoes were provided by Nfinity (Nfinity Cheer, Atlanta, GA, USA), the company that designs and creates cheer shoes worn by these specific athletes. “Old” was defined as the current season’s shoes. Participants self-reported the number of training hours that the shoes had been worn, which then allowed researchers to calculate the specific shoe age.

Additionally, participants were excluded if they had any injury to the ankle in the last three months, which caused them to miss one or more days of practice. Means and standard deviations of participant demographics are presented in Table 1. The frequency of occurrence for cheer position and shoe style are presented in Table 2. Recruitment was completed at the University cheerleading practice with the permission of the head coach. All participants were made aware of the potential risks of the study. Participants signed the informed consent approved by the University's Institutional Review Board before the starting of data collection.

Procedures

Day one of testing consisted of administrative procedures. Prior to testing, the protocol was thoroughly explained to the participant. Participants signed the informed consent once all questions were answered satisfactorily. General demographics, physical activity level information, anthropometric assessment, and physical activity readiness questionnaire (PAR-Q) were obtained from each participant. Researchers recorded individual age, height, and body mass. Moreover, participants completed the Foot and Ankle Disability Index (FADI) and the Foot and Ankle Disability Index-Sport (FADI-S) questionnaires to determine ankle sprain and ankle instability history. The experimental procedures included measurements of ground reaction force using an AMTI OR6 Series Force Platform (1000Hz, AMTI, Watertown, MA, USA). Additionally, 3D motion capture was obtained through the use of Vicon Motion Capture hardware and software (200 Hz, Vicon Motion Ltd., Version 1.8.5, Oxford, England). Participants practiced the balance trials as well as the step-down tasks onto the leveled surface as many times as desired during the familiarization session. Participants did not see the tilted platform that was used in the study during the familiarization session. However, participants were made aware, both verbally and in the written consent document, that the tilted platform would be used in the experimental session. Days two and three consisted of balance testing and step-down tasks in a randomized order.

Balance Testing

Balance testing consisted of participants completing three 20-second trials for each condition when standing on the force plate. Testing conditions were as follows: Firm Ground Bilateral Stance (FGBS), Foam Pad Bilateral Stance (FPBS), Firm Ground Dominant Leg (FGDL), Foam Pad Dominant Leg (FPDL), Firm Ground Non-Dominant Leg (FGNL), Foam Pad Non-Dominant Leg (FPNL), Firm Ground Heel Stretch (FGHS), Foam Pad Heel Stretch (FPHS), Firm Ground Arabesque (FGA), and Foam Pad Arabesque (FPA). The instructions were feet placed in specified position based on condition, hands placed on hips, looking straight ahead, and standing as still as possible. The foam pad used to further alter the proprioceptive system was an Airex Foam Pad. Only individuals who have completed a cheerleading season as a flyer within the last year were asked to complete the heel stretch and arabesque conditions as these are flyer specific positions. Trial orders were randomized for each participant.

Step-Down Task

The protocol for the step-down task was adapted from a previous study (Simpson et al., 2018). Following the completion of participant set-up and balance testing, participants were asked to complete five trials of normal step-down tasks from a height of 60 cm to a leveled surface placed 30 cm below and then take an additional step to the ground. This task was very much like walking down a flight of stairs. One minute of rest occurred between each of these five trials. After completion of the five normal step-down trials, participants were faced away from the testing area for 60 seconds and listened to the music being played on noise-cancellation headphones to take away the knowledge of the subsequent landing on either the leveled surface or the tilted surface. During the next ten trials, participants wore dribbling glasses to block the view of the platform. Subsequently, a leveled or tilted platform was placed below the 60 cm box, so the participants were unaware of the surface (leveled or tilted) on which they were stepping. The 25-degree angle for the platform was chosen based on previous literature for participant safety as ankle sprains are suggested to occur when the subtalar joint exceeds 35 degrees of inversion. The unexpected step-down surface was needed to avoid anticipatory responses and to analyze the corrective responses properly (Simpson et al., 2018). Between each of the ten total trials, if the participant stepped down onto a leveled surface, they were once again turned away from the testing area and listened to the music on noise-cancellation headphones for 60 seconds before completing the next trial. One of the ten trials was randomly selected by the investigators to place the tilted surface below the 60 cm box so that the inversion perturbation was unexpected to the participants. Neither the first or last trial could be chosen in this randomization to ensure that the perturbation was unexpected. Step-down tasks were used to mimic stepping off of a stunt and landing safely after tumbling and jumping.

Data Analysis

Lower extremity kinetics, and kinematics were analyzed using the Vicon Nexus software. Raw kinematic data were cleaned removing unlabeled markers, and marker gaps were filled using a spline fill. The kinematic marker data, as well as the analog kinetic force plate data was low pass filtered at 6 Hz using a Butterworth fourth order filter with zero lag and exported as excel files for further analyses.

Independent variables of interest included balance testing conditions and footwear conditions. Balance conditions were defined as the following: FGBS, FPBS, FGDL, FPDL, FGNL, FPNL, FGHS, FPHS, FGA, and FPA. Footwear conditions were defined as "old" and "new." Dependent variable of interest included Sway root-mean-square (RMS), Sway Velocity (Vels), Ankle Joint Angle (Ang), and Ankle Joint Angular Velocity (Vela). RMS is a measure for mean body sway and was calculated using displacement of the COP in the Anterior-Posterior (A/P) and Medial-Lateral (M/L) directions. Vels was calculated using COP displacement over the time of each trial in the A/P and M/L directions (Wade et al., 2004; Winter, 1995). Ang and Vela were calculated using Vicon Motion Capture hardware and software. Measurements from AMTI OR6 Series Force Platform were used to determine initial contact (IC). IC was identified when the ground reaction force exceeded 15 N. Both Ang and Vela were calculated within the frontal plane where ankle joint inversion and eversion occur. Ang and Vela were then classified as the maximum inversion angle and maximum velocity during the 150-ms post-IC (Simpson et al., 2018). Variables were listed as degrees and degrees per second, respectively. Once Ang was identified for each trial, Vela was calculated as displacement over time, using the following formula:

(max. Ang – IC Ang)/time from IC to max. Ang

Statistical Analysis

Descriptive and dependent variables are reported as means and standard deviations. Dependent-samples 2-tailed *t*-tests were used to analyze postural sway measures between "Old" and "New" footwear type. A 2 x 2 (footwear [Old vs New] x condition [leveled vs tilted]) repeated measures analysis of variance (ANOVA) was used to analyze time-averaged ankle movement at each discrete time point from IC to 150 ms post-IC. Cohen's (*d*) effect size was calculated for the postural control dependent measures and evaluated as small (d<0.40), medium (d=0.40–0.80), or large (d>0.80), while partial eta squared was calculated for measures of effect size within the repeated measures ANOVAs for the step-down measures. All statistical analyses were performed using SPSS version 25.0, with an *a priori* alpha level of p<.05.

Results

Analyses revealed no statistical significance for postural sway measures between "Old" and "New" shoes (p>0.05). Outcome measures for RMS and Vels are listed in Table 3. Analyses revealed a statistically significant interaction between shoe and condition when examining Ang ($F(1,24)=12.070$, $p=.002$, $\eta_p^2=.983$), showing that wearing the "old" shoe and stepping onto the tilted platform yield a greater Ang. Further investigation revealed the main effects for both shoes ($F(1,24)=85.541$, $p<.001$, $\eta_p^2=.781$) and conditions ($F(1,24)=893.489$, $p<.001$, $\eta_p^2=.974$) when examining Vela. Further analyses showed significant differences between shoe type on Vela regardless of the condition ($p < 0.001$) and differences between conditions on Vela regardless of shoe type ($p < 0.001$). Mean values for each analysis are listed in Table 4.

Discussion

The primary aim of this study was to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step-down tasks in "old" and "new" cheer shoes. Differences in RMS and Vels did not support our hypothesis of balance performance decreasing with "old" cheer shoes. While there was no statistical significance for either shoe type in any of the balance conditions, further investigation noted differences in means for variables of interest. Additionally, our hypothesis of a difference in landing mechanics between "Old" and "New" cheer shoes was supported by the significant interaction between shoes and conditions when examining the Ang. This hypothesis was further supported by the main effects of both shoes and conditions when examining Vela.

The “new” shoes showed a greater mean value for Vels for the conditions of FGBS, FGNL, FGA, FPHS and FGHS in the medial-lateral (M/L) and anterior-posterior (A/P) directions and FGDL in the A/P directions. The “old” shoes showed a greater mean value for Vels for the conditions of FPBS, FPDL, and FPA in the M/L and A/P directions and FGDL in the M/L directions. Vels is a measure of the change of the COP per unit of time and is representative of changes in the location of the COP in M/L and A/P directions. Greater values of Vels imply larger changes in the COP, indicating a decrease in postural stability (Wade et al., 2004). Additionally, “new” shoes were noted to have greater mean values for RMS for the conditions of FGNL, FPNL, FPA, FGA and FPHS in the M/L and A/P directions. “Old” shoes were noted to have greater mean values for RMS for the conditions of FPBS and FPDL in the M/L and A/P directions. RMS denotes a measure for mean body sway of a specific period of time allowing for a comparison to be made between conditions (Wade et al., 2004). An increase in RMS denotes a larger sway area, indicating a decrease in postural stability as well (Winter, Prince, Stergiou & Powell, 1993). While further examining the data, it is important to note that sway in the A/P directions reflect motor responses of the dorsiflexors and plantar flexors while sway in the M/L directions reflects motor responses of the ankle invertors and evertors (Winter, Prince, Stergiou & Powell, 1993). Understanding this relationship can help decipher the relationship between the shoe type and decrements in balance.

The increase in Vels and RMS for “new” shoes on the firm ground conditions is contradictory to findings in current literature. As previously noted, footwear serves as the interface between the lower extremity and the surrounding environment. Researchers found that outsoles and midsoles were better for balance maintenance (Chander, Morris, Wilson, Garner & Wade, 2016). Because the proprioceptive system detects external stimuli, alterations to the system cause more prominent balance deficits. Interferences to the proprioceptive system impair the ability to detect changes in the surface stability, temperature, incline, decline, and depth of steps (Hong, Park, Kwon, Kim & Koo, 2014; Tiseo, Foo, Veluvolu, & Tech, 2018; Westcott et al., 1997). Attenuation of the external information being received should theoretically show an improvement in balance when wearing “new” shoes. However, further researcher is needed to determine why this may not be the case for “new” cheer shoes on firm ground Additionally, “new” shoes may demonstrate better balance characteristics for foam pad trials because the hardness of the midsole and outsole of the shoe is able to attenuate forces (Chander, Morris, Wilson, Garner & Wade, 2016). Inversely, this same concept can be applied to explain the balance differences in “old” shoes for the firm ground and foam pad trials. Previous literature notes that a decrease in midsole and outsole hardness leads to decreases in the ability to maintain balance within a variety of populations (Aquino, Amasay, Shapiro, Kuo & Ambegaonkar, 2019; Chander, Morris, Wilson, Garner & Wade, 2016; Kong, Candelaria & Smith, 2009). Theoretically, “old” shoes should display an overall decrease in balance when compared to the “new” shoes. Consistent with current literature is the decrease in ability to maintain balance for foam pad trials when wearing “old” shoes. (Aquino, Amasay, Shapiro, Kuo & Ambegaonkar, 2019) This decrement could be explained by the decrease in midsole and outsole hardness, as well as the overall decrease in stiffness of the shoe, decreasing the shoes’ ability to attenuate forces (Chander, Morris, Wilson, Garner & Wade, 2016). Aquino Amasay, Shapiro, Kuo and Ambegaonkar (2019) note that professional dancers had greater sway values in a variety of dance-specific positions, further suggesting that “old” shoes may be unfavorable for performance as this may increase the chance of injury. While these findings display some confounding results, further research is needed to thoroughly explain the effect that shoe age has on balance maintenance within the cheerleading population.

When examining the step-down tasks, Ang and Vela were investigated. A statistically significant interaction was observed between shoe type and platform condition for Ang. Data showed that the Ang was highest with the “old” shoe and tilted platform. While the increased angle for the tilted platform is to be expected as the surface is tilted at a 25-degree angle, the increased Ang for “old” shoes may be explained by the decrease in structural characteristics of the shoe itself. Kong, Candelaria and Smith (2009) conducted a study that produced results showing that as shoe cushioning capabilities decreased, runners changed their previous running patterns to attenuate the ground reaction forces, which could possibly predispose them to ankle injury. While running has been a large focus in previous literature, the fundamentals behind shoe design and wear and tear continue across a number of athletic populations. Additionally, researchers note that the shoe midsole act as the first filters for ground reaction forces, which can greatly affect the transfer of information to the proprioceptors of the foot that trigger corrective mechanisms (Reinschmidt & Nigg, 2000). Significant main effects were found in both shoe type and platform condition for the Vela. These findings suggest that Vela is greater with the “old” shoe regardless of the platform type and greater with the tilted platform regardless of shoe type. Much like the increased Ang, these findings may be best explained by the decrease in structural characteristics of the “old” shoe. Literature notes that unexpected ankle inversion perturbations, much like that of the tilted platform, yield greater Angs and Ang velocities (Simpson et al., 2018). The unexpected perturbation recruits corrective responses that would not have been properly engaged should the individual have known about the perturbation prior to stepping down. The increases in both Ang and Vela with the “old” shoe may be explained by the decrease in structural characteristics of the shoe itself. Cheerleading specific footwear is designed to have a low mass, slip resistant rubber outsoles, and EVA foam midsoles to provide cushioning and shock absorption. Previous research has shown that these characteristics influence subtalar joint adaptability, range of motion, and ground reaction force attenuation capabilities. Furthermore, these design characteristics have been attributed to reductions in postural stability, and somatosensory and proprioceptive feedback from cutaneous receptors of the foot/ankle (Simpson et al., 2018; Simpson, DeBusk, Hill, Knight & Chander, 2018). Additionally, previous research has noted that low cut shoes provide a greater range of motion for the ankle joint when compared to shoes with greater ankle shafts (Avramakis, Stakoff & Stussi, 2000; Daack & Senchina, 2017). While an increased range of motion may be ideal for performing sport-specific movements within cheerleading, a low cut shoe that has decreased structural integrity may be cause for concern when looking to prevent ankle injury. The specific shoes that participants wore were low profile, mesh or cloth body and EVA or rubber outsoles. These specific characteristics attributing to light weight may be ideal for cheer shoes as increased mass at the foot can make performing sport specific skills more difficult. However, as the soles and shoe body wear down and weaken throughout continued use, the shoe no longer has the structural support that was originally intended (Jacobson, Redus & Palmer, 2005; Shields & Smith, 2006). This information can aid in explaining the increase in Vela and Ang with “old” shoes.

Conclusion

When examining the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step-down tasks in “old” and “new” cheer shoes, it would seem that different shoe types may be better suited for specific tasks. While there was no statistical significance in initial analyses, differences in mean values may support the idea that “old” shoes seem to display better balance characteristics within this specific population. Inversely, “new” shoes display better landing mechanics and decreased risk of injury as they have a lesser Ang and Vela. To be able to draw firm conclusions, further investigation into these differences within the cheerleading population is needed.

Table 1. Participant Demographics (Mean ± SD)

	Mean ± SD
Age (years)	19.9 ± 1.4
Mass (kg)	62.0 ± 9.3
Height (cm)	162.7 ± 6.7
Shoe size	8.2 ± 2.2
"Old" shoe age (training hours)	426.4 ± 290.2

Table 2. Additional Descriptive Statistics

	Total number
Sport Position	Base: 16
	Flyer: 9
Shoe Style (Old & New)	Evolution: 13
	Flyte: 6
	Vengeance: 6

Table 3. Outcome measures for Average RMS and Vels

		RMS		Vels	
AP/ML	Condition	Mean Difference (SD)	*P* value (Cohens *d*)	Mean Difference (SD)	*P* value (Cohens *d*)
AP	FGBS	0.032 (0.126)	0.222 (0.267)	0.520 (2.949)	0.387 (0.124)
	FGDL	0.026 (0.289)	0.657 (0.110)	0.320 (3.611)	0.623 (0.081)
	FGNL	0.011 (0.228)	0.812 (0.060)	0.312 (3.413)	0.651 (0.071)
	FGHS	-0.232 (0.447)	0.183 (0.541)	-0.193 (0.917)	0.545 (0.106)
	FGA	-0.041 (0.257)	0.650 (0.259)	-0.153 (1.325)	0.737 (0.085)
	FPBS	-0.003 (0.173)	0.938 (0.021)	-0.241 (1.691)	0.483 (0.060)
	FPDL	-0.096 (0.648)	0.468 (0.174)	-0.457 (1.947)	0.252 (0.115)
	FPNL	0.589 (1.630)	0.083 (0.576)	15.183 (73.419)	0.311 (0.394)
	FPHS	-0.266 (1.526)	0.615 (0.134)	-1.981 (11.164)	0.609 (0.246)
	FPA	-0.079 (0.749)	0.759 (0.161)	0.822 (3.516)	0.503 (0.308)
ML	FGBS	-0.001 (0.139)	0.970 (0.006)	0.606 (2.263)	0.193 (0.172)
	FGDL	-0.001 (0.205)	0.990 (0.003)	-0.002 (3.238)	0.997 (0.001)
	FGNL	0.016 (0.251)	0.746 (0.070)	0.405 (3.072)	0.516 (0.110)
	FGHS	0.028 (0.317)	0.798 (0.065)	-0.152 (1.592)	0.782 (0.066)
	FGA	-0.121 (0.321)	0.290 (0.537)	-0.419 (1.364)	0.384 (0.252)
	FPBS	-0.044 (0.178)	0.225 (0.222)	-0.196 (1.348)	0.474 (0.061)
	FPDL	-0.037 (0.214)	0.391 (0.118)	-0.106 (1.466)	0.722 (0.035)
	FPNL	0.325 (1.112)	0.157 (0.483)	12.316 (61.389)	0.326 (0.383)
	FPHS	-0.192 (0.884)	0.532 (0.183)	-1.089 (6.173)	0.611 (0.231)
	FPA	-0.083 (0.599)	0.689 (0.188)	0.734 (3.665)	0.565 (0.283)

Table 4. Ankle kinematics during leveled and tilted landing conditions in “Old and “New” shoes mean (SEM)

	New Shoe		Old Shoe		*p* Value (η^2)		
Variable	Leveled	Tilted	Leveled	Tilted	Condition	Shoe	Interaction
Inversion Angle (°)	5.424 (0.480)	17.897 (0.827)	5.855 (0.447)	22.107 (0.634)	*p*<0.001 (0.963)	p=0.002 (0.345)	*p*=0.002 (0.983)
Inversion Velocity (°/s)	0.005 (0.002)	119.313 (5.513)	39.034 (2.978)	147.382 (4.230)	*p*<0.001 (0.974)	*p*<0.001 (0.781)	p=0.133 (0.092)

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CHAPTER 2: EXTENDED METHODS

Purpose

The purpose of this study was to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step-down tasks in “old” and “new” cheer shoes.

Participants

We recruited 25 participants (males: 5, females: 20) by verbal presentation at cheerleading practices with permission of the head coach.

Exclusion Criteria:

1. Lower extremity injury within the last 3 months that hindered sport participation
2. No “old” shoes that fit the classification criteria
3. Lack of physical activity participation
4. Any neurological or musculoskeletal disease or disorder
5. Current concussion
6. Allergic to adhesive

Inclusion Criteria:

1. Collegiate cheerleaders between the ages of 18-25
2. Enrolled in academic course at Georgia Southern
3. One “old” pair of shoes that fit the classification criteria
4. No history of lower extremity fracture surgery or ankle sprain within the last three months

5. Free of neurological or musculoskeletal disease or disorder
6. No current concussion
7. Participate in a moderate amount of physical activity
    a. 150 minutes or more of moderate exercise per week
    b. 75 minutes or more of vigorous exercise per week
8. Not allergic to adhesive

All subjects were identified according to coded numbers (i.e. AZ01) to keep participants' information confidential. All data was processed, analyzed and interpreted using these numbers and any documents obtained from participants were kept in a locked filing cabinet. Subjects received no incentives for their participation in this study.

Protocol

This study was performed in the Biomechanics Laboratory at Georgia Southern University. Testing took place over three days separated by at least 48 hours for every participant. The first day of testing included preliminary paperwork, demographic information collection and familiarization, lasting for approximately 30 minutes. The second and third days of testing lasted approximately an hour each and consisted of balance testing and step-down tasks. The participants were informed of the testing protocols and possible risks prior to testing. Once all questions were answered satisfactorily, participants signed the informed consent form. Additionally, participants were asked to complete a physical activity readiness questionnaire (PAR-Q), Foot and Ankle Disability Index (FADI), FADI-Sport, and Shoe Age Guide to calculate school age of the “old” shoe. The experimental procedures included measurements of ground reaction force, and 3D motion capture using an AMTI OR6 Series Force Platform (1000Hz, AMTI, Watertown, MA, USA), Vicon Motion Capture software (Vicon Motion Ltd., Version 1.8.5, Oxford, England) was used to record each trial throughout testing protocol. 3D motion capture was used to assess changes in body movement such as joint angles and linear and angular velocity. The 3D motion capture software was used (Vicon Motion Ltd., Version 1.8.5, Oxford, England) to build a skeletal model of the participant's lower extremity. Marker sets were placed on the participants' ASIS, PSIS, thighs, lateral epicondyles, legs, lateral malleoli, calcanei, and fifth head of the metatarsals. For balance testing, participants completed standing balance tests consisting of three 20 s trials for each condition. Testing conditions were as follows: Firm Ground (FG) Bilateral Stance, Foam Pad (FP) Bilateral Stance, FG Dominant Leg, FP Dominant Leg FG Non-Dominant Leg, FP Non-Dominant Leg, FG Heel Stretch, FP Heel Stretch, FG Arabesque and FP Arabesque. For step-down tasks, participants completed five normal step-down tasks from a 60 cm box to a leveled surface 30 cm below then took a final step to the ground, much like walking down a flight of stairs. After completing these five trials, participants faced away from the testing area and listened to music on noise cancelling headphones for 60 seconds. Participants then completed up to 10 trials in which one of the trials was an unexpected tilted platform. Participants were made aware that one of the trials would be a tilted platform before testing began. A 60 second break took place between each of these trials. All trials were randomized for each participant.

Data Processing

The ten balance conditions on the force platform used participants' center of pressure to quantify postural sway. The dependent variables of interest were the Vels components in the medial-lateral (M/L) and anterior-posterior (A/P) directions, and root mean square (RMS) of COP displacement in the AP and ML directions. Lower extremity movement and forces during the step-down task were calculated using Vicon Nexus software. Specifically, ankle movement was analyzed at each discrete time point from Initial Contact (IC) to 150 ms post-IC for each landing trial. IC was identified when the vertical component of the ground reaction force exceeded 15 N. Maximum ankle inversion velocity and maximum inversion angle, measured in degrees per second and degrees, respectively, was defined as the maximum velocity and maximum inversion angle during the 150-ms post-IC period.

Statistical Analysis

Dependent-samples 2-tailed t tests were used to analyze postural sway measures between “Old” and “New” footwear conditions. A 2 x 2 (footwear [New vs Dead] x condition [leveled vs inverted] repeated measures analysis of variance was used to analyze time-averaged ankle movement at each discrete time point from 150 ms pre-IC to 150 ms post-IC. Cohen’s (d) effect size data was calculated for the postural control dependent measures and evaluated as small ($d<0.40$), medium ($d=0.40 – 0.80$), or large ($d>0.80$), while partial eta squared was calculated for measures of effect size within the repeated measures ANOVAs for step-down measures.

CHAPTER 3: SAMPLE JOURNAL ARTICLE

Introduction

Cheerleading participation is growing at a rate of 18% per year in the United States. Athletes are starting to participate in cheerleading as young as the age of 5 (Meyer, Oddsson, & De Luca, 2004; Nigg, Baltich, Hoerzer & Enders, 2015). Overall, in all age groups of cheerleading, the leading mechanism of injury is due to falls (29.4%), and sprains and strains are the most common types of injuries sustained, accounting for 53% of all injuries. Further, the most commonly injured joint is the ankle joint, accounting for 44.9% of all injuries, specifically involving damage to the lateral ligaments of the ankle, and result from injuries with the ankle in a plantar-flexed position (Jacobson et al., 2004). Lateral ankle sprains, which damage the lateral ankle ligaments result from excessive subtalar inversion or a combination of subtalar inversion, internal rotation, and talocrural plantar flexion about an externally rotated distal tibia during ground contact. Landing from a jump requires ankle plantar flexion and in some cases ankle inversion to attenuate large and rapid loads when landing, which can initiate the mechanism of a lateral ankle sprain. The rapid and unexpected joint perturbations that can occur when landing can generate large supination moments of the ankle complex that can result in damage to the lateral ankle ligaments (Shields & Smith, 2011). An important contributor to fall risk is the control of posture. Postural control involves many different underlying physiological systems such as visual acuity, somatosensory and vestibular function. Alterations to any of these systems may result in balance decrements, and increased fall risk (Simpson, DeBusk, Hill, Knight & Chander, 2018). Because footwear serves as the interface between the human foot and the external environment, it plays a vital role in the maintenance of postural control, and balance. (Chander, Morris, Wilson, Garner & Wade, 2016). Standard footwear characteristics that influence postural control are footwear mass, shaft height, outsole/midsole hardness, and heel height. Cheerleading specific footwear is designed to have a low mass, slip resistant rubber outsoles, and EVA foam midsoles to provide cushioning and shock absorption. Previous research has shown that these characteristics influence subtalar joint adaptability, range of motion, and ground reaction force attenuation capabilities. Furthermore, these design characteristics have been attributed to reductions in postural stability, and somatosensory and proprioceptive feedback from cutaneous receptors of the foot/ankle (Simpson, DeBusk, Hill, Knight & Chander, 2018). Although evidence regarding changes in the structural integrity of cheerleading specific shoes and how they affect lower extremity biomechanics is limited, decrements in postural control, and lower extremity mechanics have been reported in other types of athletic footwear. Early work on footwear biomechanics suggests that runners should change their running shoes every 300-400 miles to accommodate for decreases of shock absorption properties. It was further reported that the main changes observed in response to the increased “milage” or use of the running shoe is at the ankle (Aquino, Amasay, Shapiro, Kuo & Ambegaonkar, 2019). More recent work examined the effects of “new” compared to “dead” pointe shoes in professional ballet dancers. Suggesting lower extremity biomechanics were altered between footwear conditions. Specifically, it was observed that the “dead” pointe shoes decreased balance during ballet specific skills, as well as increased muscle activity of the lower extremities. This suggests that the wear and tear of the pointe shoes may increase lower extremity injury risk in dancers (Aquino, Amasay, Shapiro, Kuo & Ambegaonkar, 2019). Limited information is available regarding the effects of cheerleading specific footwear on balance and lower extremity biomechanics during landing, or how continued “wear and tear” of cheer shoes may alter these effects.. Therefore, the aim of this study is to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step-down tasks in “dead” and “new” cheer shoes

Methods

Male and female collegiate cheerleaders were recruited from university in southeast Georgia, all between the ages of 18 and 25 years (Table 1). Inclusion criteria required participants to own one pair of “old” personal cheer shoes, have no history of lower extremity fracture, surgery, or ankle sprain within the last three months, and participate in a moderate amount of physical activity. Exclusion criteria included ankle injury within the last three month, lack of physical activity participation, any neurological or musculoskeletal disorder, or no “old” pair of personal cheer shoes. Since participants were asked to bring their own shoes, shoe age was calculated for the “old” shoes. “New” shoes were provided by the researchers. “Old” shoes were defined as the current season’s shoes while “new” shoes were defined as never having been worn, taken out of the box soley for testing purposes.

Table 1. Cheerleaders demographics and shoe age (Mean ± SD), *n=25*

	Mean ± SD
Age (years)	19.88 ± 1.36
Mass (kg)	61.94 ± 9.33
Height (cm)	162.70 ± 6.68
Shoe size	8.18 ± 2.23
“Old” shoe age (training hours)	426.36 ± 290.16

Instrumentation

The experimental procedures included measurements of ground reaction force using an AMTI OR6 Series Force Platform (1000Hz, AMTI, Watertown, MA, USA). Vicon Motion Capture software (Vicon Motion Ltd., Version 1.8.5, Oxford, England) was used to record each trial throughout testing protocol. 3D motion capture was used to assess changes in body movement such as joint angles and linear and angular velocity.

Procedures

Testing took place over three days separated by at least 48 hours for every participant. The first day of testing included preliminary paperwork, demographic information collection and familiarization, lasting for approximately 30 minutes. The second and third days of testing lasted approximately an hour each and consisted of balance testing and step-down tasks. Prior to testing beginning, participants were informed of the testing protocols and possible risks prior to testing. Once all questions were answered satisfactorily, participants signed the informed consent form approved by Georgia Southern University Institutional Review Board. Additionally, participants were asked to complete a physical activity readiness questionnaire (PAR-Q), Foot and Ankle Disability Index (FADI), FADI-Sport, and Shoe Age Guide to calculate school age of the "old" shoe. Participants were asked to wear athletic clothes, which allowed for adequate retroreflective marker placement.

Shoe Age Calculation

*Shoe Age=(Number of Football Games Cheered * 4 hours) + (Number of Basketball Games Cheered * 2 hours) + (9 hours of practice per week * Number of weeks worn) + (Number of NCA Competitions worn * 5 hours) + (Number of additional training hours worn)*

Participants’ anthropometrics were taken prior to beginning testing using a measuring tape to collect knee and ankle joint widths and leg length as dictated by Vicon Nexus software (Vicon Motion Systems Ltd., Oxford, England). Participants stretched as preparing for testing sequences. Retroreflective markers were placed on the participants' ASIS, PSIS, thighs, lateral epicondyles, legs, lateral malleoli, calcanei, and fifth head of the metatarsals. For balance testing, participants completed standing balance tests consisting of three, 20-second trials for each condition. Testing conditions were as follows: Firm Ground (FG) Bilateral Stance, Foam Pad (FP) Bilateral Stance, FG Dominant Leg, FP Dominant Leg FG Non-Dominant Leg, FP Non-Dominant Leg, FG Heel Stretch, FP Heel Stretch, FG Arabesque and FP Arabesque. For step-down tasks, participants completed five normal step-down tasks from a 60 cm box to a leveled surface 30 cm below then took a final step to the ground, much like walking down a flight of stairs. One minute of rest was taken between each trial. After completing these five trials, participants faced away from the testing area and listened to music on noise cancelling headphones for 60 seconds. Participants then completed up to 10 trials in which one of the trials was an unexpected tilted platform. Participants were made aware that one of the trials would be a tilted platform before testing began. A 60 second break took place between each of these trials. All trials and shoe types were randomized for each participant.

Data Processing and Statistical Analysis

This study was a repeated measures, randomized design. Each participant completed testing in “old” and “new” cheer shoes. The ten balance conditions on the force platform used participants’ center of pressure to quantify postural sway. The dependent variables of interest were the Vels components in the medial-lateral (M/L) and anterior-posterior (A/P) directions, and root mean square (RMS) of COP displacement in the A/P and M/L directions. Lower extremity movement and forces during the step-down task were calculated using Vicon Nexus software. Specifically, ankle movement was analyzed at each discrete time point from Initial Contact (IC) to 150 ms post-IC for each landing trial. IC was identified when the vertical component of the ground reaction force exceeded 15 N. Maximum ankle inversion velocity and maximum inversion angle, measured in degrees per second and degrees, respectively, was defined as the maximum velocity and maximum inversion angle during the 150-ms post-IC period.

Data was processed using Nexus 2.1.7 software (Vicon Motion Systems Ltd., Oxford England) and SPSS (IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY) with an a priori alpha level of $p<.05$. Dependent-samples 2-tailed t tests were used to analyze postural sway measures between “Old” and “New” footwear conditions. A 2 x 2 (footwear [New vs Dead] x condition [leveled vs inverted] repeated measures analysis of variance was used to analyze time-averaged ankle movement at each discrete time point from 150 ms pre-IC to 150 ms post-IC. Cohen’s (d) effect size data was calculated for the postural control dependent measures and evaluated as small ($d<0.40$), medium ($d=0.40 – 0.80$), or large ($d>0.80$), while partial eta squared was calculated for measures of effect size within the repeated measures ANOVAs for step-down measures.

Results

Analyses revealed no statistical significance for postural sway measures between “Old” and “New” shoes ($p>0.05$). A statistically significant interaction was found between shoe and condition when examining the Ang ($F(1,24)=12.070$, $p=.002$) showing that wearing the “old” shoe and stepping onto the tilted platform yield a greater Ang. Further investigation revealed main effects of both shoe ($F(1,24)=85.541$, $p<.001$) and condition ($F(1,24)=893.489$, $p<.001$)

when examining Vela. Pairwise comparisons show significant differences between shoe type on Vela regardless of the condition ($p<.001$) and differences between condition on Vela regardless of shoe type ($p<.001$).

Discussion

The primary aim of this study was to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step-down tasks in "old" and "new" cheer shoes. While there was no statistical significance for either shoe type in any of the balance conditions, further investigation noted differences in means for variables of interest. The "new" shoes showed a greater mean value for Vels for the firm ground conditions in the medial-lateral (M/L) and anterior-posterior (A/P) directions. The "old" shoes showed a greater mean value for Vels for the foam pad conditions in the M/L and A/P directions greater values of Vels imply larger changes in the COP, indicating a decrease in postural stability (Wade et al., 2004). Additionally, "new" shoes were noted to have greater mean values for RMS for 5 of 10 conditions in the M/L and A/P directions. "Old" shoes were noted to have greater mean values for RMS for 2 of 10 conditions in the M/L and A/P directions. An increase in RMS denotes a larger sway area, indicating a decrease in postural stability as well (Winter, Prince, Stergiou & Powell, 1993).

While further examining the data, it is important to note that sway in the A/P directions reflect motor responses of the dorsiflexors and plantar flexors while sway in the M/L directions reflect motor responses of the ankle invertors and evertors (Winter, Prince, Stergiou & Powell, 1993). Understanding this relationship can help decipher the relationship between the shoe type and decrements in balance. As previously noted, footwear serves as the interface between the lower extremity and the surrounding environment (Chander, Morris, Wilson, Garner & Wade, 2016). The increase in Vels and RMS for “new” shoes on the firm ground conditions could be explained by the lack of feedback received from foot and ankle proprioceptors due to the attenuation caused by hardness and structural integrity of the shoes. Because the proprioceptive system detects external stimuli, alterations to the system cause more prominent balance deficits. Interferences to the proprioceptive system impair the ability to detect changes in the surface stability, temperature, incline, decline, and depth of steps (Hong, Park, Kwon, Kim & Koo, 2014; Tiseo, Foo, Veluvolu, & Tech, 2018; Westcott et al., 1997). Additionally, “new” shoes may demonstrate better balance characteristics for foam pad trials because the hardness of the midsole and outsole of the shoe is able to attenuate forces (Chander, Morris, Wilson, Garner & Wade, 2016). Inversely, this same concept can be applied to explain the balance differences in “old” shoes for the firm ground and foam pad trials. “Old” shoes may demonstrate better balance on firm ground trials as the decrease in midsole and outsole hardness, as well as the overall decrease in stiffness of the shoe, allows for the proprioceptors and cutaneous receptors to better receive feedback. Receiving this feedback allows for faster corrective responses to occur, further maintaining balance (Winter, 1995). The decrement in the ability for “old” shoes to maintain balance on foam pad could be explained by the decrease in midsole and outsole hardness, as well as the overall decrease in stiffness of the shoe, decreasing the shoes’ ability to attenuate forces (Chander, Morris, Wilson, Garner & Wade, 2016).

Additionally, our hypothesis of a difference in landing mechanics between “Old” and “New” cheer shoes was supported by an interaction between shoe and condition when examining the Ang. This hypothesis was further supported by main effects of both shoe and condition when examining Vela. Data showed that the Ang was highest with the “old” shoe and tilted platform. While the increased angle for the tilted platform is to be expected as the surface is tilted at a 25 degree angle, the increased Ang for “old” shoes may be explained by the decrease in structural characteristics of the shoe itself. Significant main effects were found in both shoe type and platform condition for the Vela. These findings suggest that Vela is greater with the “old” shoe regardless of the platform type and greater with the tilted platform regardless of shoe type. The increases in both Ang and Vela with the “old” shoe may be explained by the decrease in structural characteristics of the shoe itself. Cheerleading specific footwear is designed to have a low mass, slip resistant rubber outsoles, and EVA foam midsoles to provide cushioning and shock absorption. Previous research has shown that these characteristics influence subtalar joint adaptability, range of motion, and ground reaction force attenuation capabilities. Furthermore, these design characteristics have been attributed to reductions in postural stability, and somatosensory and proprioceptive feedback from cutaneous receptors of the foot/ankle (Simpson et al., 2018; Simpson, DeBusk, Hill, Knight & Chander, 2018). The specific shoes that participants wore were low profile, mesh or cloth body and EVA or rubber outsoles. These specific characteristics were chosen to be light weight as increased weight at the foot can make performing sport specific skills more difficult. However, as the soles and shoe body wear down and weaken throughout continued use, the shoe no longer has the structural support that was originally intended (Jacobson, Redus & Palmer, 2005; Shields & Smith, 2006). This information can aid in explaining the increase in Vela and Ang with “old” shoes

Conclusions

We found that biomechanical differences are exhibited by collegiate cheerleaders while performing balance testing and step-down tasks in “old” and “new” cheer shoes. While all findings may not be statistically significant, it would seem that different shoe types may be better suited for specific tasks. “Old” shoes display lower mean values for RMS and Vels, noting better maintenance of balance. On the contrary, “new” shoes display lower values for Ang and Vela, noting better corrective responses associated with landing mechanics. Further investigation into these differences within the cheerleading population is needed to identify how shoe age affects balance and landing mechanics.

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APPENDIX A: EXTENDED INTRODUCTION

Specific Aims

1. To investigate the effect of shoe age on balance and postural sway.
    a. H_{O1}: There will be no change in balance performance between “Old” and “New” cheer shoes
    b. H_{A1}: Balance performance will be decreased with “old” cheer shoes than with “new” shoes
2. To investigate the effect of shoe age on landing mechanics during single leg drop landings.
    a. H_{O2}: There will be no difference in landing mechanics between “Old” and “New” cheer shoes
    b. H_{A2}: There will be a difference in landing mechanics between “Old” and “New” cheer shoes

Independent Variables

1. Shoe Type
    a. Old
    b. New
2. Testing Conditions
    a. Firm Ground
        i. Bilateral Stance
        ii. Non-Dominant
        iii. Dominant

iv. Heel Stretch
v. Arabesque

b. Foam Pad
i. Bilateral Stance
ii. Non-Dominant
iii. Dominant
iv. Heel Stretch
v. Arabesque

c. Step-Down Platform
i. Leveled
ii. Tilted

Dependent Variables

1. RMS
2. Vels
3. Ang
4. Vela

Limitations

1. Participants recruited from one southeastern university's cheerleading team

Delimitations

1. Participants were college cheerleaders between the ages of 18 -25
2. Participants owned one pair of old shoes
3. Participants could not have had an injury within the last 3 months

Assumptions

1. All equipment was calibrated in the appropriate manner before each testing session.
2. The retro-reflective markers were placed correctly on the appropriate anatomical landmarks.
3. Participants gave an accurate report of information on shoe age and all questionnaires.

Operational Definitions

1. Balance: The ability to maintain an individual's center of gravity within the base of support to prevent falling (Tiseo, Foo, Veluvolu, & Tech, 2018).
2. Posture: The position of various body parts with respect to one another, the environment, and gravity (Tiseo, Foo, Veluvolu, & Tech, 2018).
3. Center of Mass (CoM): the center point of the average mass, relative to all parts of the system (Dutt-Mazumder, Challis & Newell, 2016).
4. Center of Gravity (CoG): the point on the ground that represents the vertical projection of the Center of Mass (Winter, 1995).
5. Base of Support (BoS): The area in which an individual comes into contact with an exterior surface, most commonly defined as the area from the heels to toes of both feet (Tiseo, Foo, Veluvolu, & Tech, 2018).
6. Center of Pressure (CoP): the average of all pressures over the surface area in which the individual is in contact with, most commonly the surface area in which the feet are in contact with (Winter, 1995).
7. Postural Sway: the quantification of changes in Center of Pressure (Winter, 1995).
8. Postural Control: restoration, achievement, or maintenance of balance during any postural related activity (Pollock, Durward, Rowe, & Paul, 2000).

9. Proprioceptive System: The sensory system composed of numerous detectors that provide body and limb position, contributing to the maintenance of balance (Winter, 1995).
10. Visual System: The sensory system involved in planning movement and avoiding hindrances along the way via the eyes (Winter, 1995).
11. Vestibular System: The sensory system involved in the regulation of body alignment and detection of the angular and linear acceleration of the head through the use of inner ear structures (Winter, 1995).
12. Step-down task: the action of stepping down from a 60 cm box on to a leveled or tilted platform 30 cm below. Much like walking down a flight of stairs
13. Cheerleading: A co-ed sport involving gymnastic and acrobatic-like movements
14. Cheer shoes: light weight shoes worn during sport specific practices and events
15. New Shoes: cheer shoes that have never been worn; only taken out of the box for testing purposes
16. Old Shoes: Participants' current season's cheer shoes
17. Flyer: sport position; the individual held in the air by bases
18. Base: sport position; the individual holding the flyer above their head
19. Heel Stretch: a sport specific movement performed by flyers in which their non-support leg is held by the arch of the foot, fully-extended, in front of the shoulder
20. Arabesque: a sport specific movement performed by flyers in which their non-support leg is extended directly behind the body, forming a T-shape with the support leg and chest

APPENDIX B: EXTENDED LITERATURE REVIEW

The purpose of this study is to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step-down tasks in “old” and “new” cheer shoes. This chapter is separated into three major sections. The first will provide a basic understanding of cheerleading and injury. The second will provide a definition of balance and the various systems and factors that maintain and effect balance. Finally, this chapter will examine sporting footwear and the various aspects that can affect sport performance and injury.

Cheerleading

Cheerleading is a sport that requires athletes to perform a variety of acrobatic skills. These movements that are performed are closely related to that of gymnastics and acro-tumbling. (Jacobson, Redus, & Palmer, 2005; Shields & Smith, 2006; Shields & Smith, 2011). In order to properly perform these skills, cheerleaders need to be able to generate explosive force, much like many other power athletes (Zalleg, et al. 2018). Much like gymnastics, with both stunting and tumbling, the lower extremities serve as weight bearing limbs that see repetitive impacts at approximately four times of the individual's body weight (Farana, Jandacka, Uchytil, Zahradnik, & Irwin, 2013). Cheerleading has grown substantially since its conception in the late 1800’s. Cheerleaders have transitioned from simple sideline chants and crowd leading to skillful acrobatics and pyramids (Waters, 2012). In December of 2016, cheerleading was officially recognized by the International Olympic Committee and is working towards incorporation into the Olympic Competition (Eckley, 2018). Although cheerleading originated in the U.S., the sport has become a worldwide phenomenon. Approximately one million individuals, ranging from children to adults, participate in this sport (Jacobson, Redus, & Palmer, 2005). On average, collegiate cheerleaders practice three to five days a week for two to four hours per session during the school year (August to May). This approximates for 150 days of regularly scheduled practice in which skills are performed (Jacobson, Redus, & Palmer 2005; Shields & Smith, 2006; Shields & Smith, 2011). The majority of practices occur on a standard cheerleading mat which is made of 2 to 4-inch thick foam with ¼-inch carpet as a top layer. Other surfaces that cheerleading skills may be performed on at the collegiate level include turf, grass, and basketball gym flooring (Shields & Smith, 2009). Additionally, the ability of the landing surface, such as the mat, flooring, or turf, to absorb landing forces can play a role in injury severity (Shields & Smith, 2009). Much like any other athlete, cheerleaders are at risk of injury due to the demands of the sport. Tumbling and stunts are the leading cause of injury with the cheerleading population. Falls are the leading mechanism of injury while sprains and strains account for the most common types of injuries sustained (Jacobson et al., 2004). Approximately 45% of sprains and strains occur at the ankle joint with specific damage to the lateral ligaments, classifying the injuries and lateral, or inversion, ankle sprains (Jacobson et al., 2004).

Balance

The ability to maintain balance and postural control are integral, functional activities of daily living. Humans' bipedal mobility creates a unique demand for our postural control system. For normal healthy populations, the task of maintaining balance is intensified by the fact that the center of mass is located at approximately two-thirds of our body height (Winter, 1995). Stabilizing, or balancing, in an upright stance involves numerous joints and muscles relying on an intricate coordination process. Previous studies have defined balance as the ability to maintain the center of mass to stay within the boundaries of the base of support (Dutt-Mazumder, Challis & Newell, 2014; Wang, Ko, Challis, & Newell, 2014). The area of the base of support acts as constraints for the maintenance of balance. Postural control is maintained through complex communication between the vestibular, visual and somatosensory systems. Disturbances or deficits in this communication can lead to loss of balance and coordination. Alterations to each system do not cause postural deficits equally but rather cause deficits unique to certain situations. The vestibular system is involved in the regulation of body alignment and detection of angular and linear acceleration of the head through the use of inner ear structures. These detections are used to maintain level gaze along the horizon. Information received by the vestibular system can also be used to control eye movement to stay focused on a fixed point while the head changes position. The vestibular system is the slowest of the three sensory systems and often recruited last for balance maintenance and postural adjustments. The vestibular system also works to discern conflicting information from the visual and proprioceptive systems (Winter, 1995). When alterations are made to the vestibular system, the visual and proprioceptive systems begin to compensate for the alterations. Dizziness or vertigo may result from impairment of the vestibular system but can be counteracted or prevented through the increased reliance on input from the visual system (Winter 1995; Audu & Daly, 2017). The increased reliance on visual input allows for the creation and dependence of visual reference points to prevent balance deficits (Murray, Salvatore, Powell, & Reed-Jones, 2014; Westcott et al., 1997). The first system used to make postural adjustments is the visual system which receives feedback from the environment as our body moves through it. After receiving input from the eyes, the visual system becomes involved in planning movement and avoiding hindrances along the way. The visual system is highly integrated with both the vestibular and proprioceptive systems and communicates information to both systems in order to maintain balance. Under normal conditions, the visual and proprioceptive systems are relied on heavily to maintain balance but alterations to the visual system increase reliance on the vestibular and proprioceptive systems (Pavao et al., 2014; Shielder et al., 2018). The proprioceptive system receives feedback from proprioceptors all over the body relaying information about the environment and joint segments position and orientation. Additionally, cutaneous receptors relay information about external stimuli that detect sensations such as pressure, temperature, and touch (Winter 1995; Audu & Daly, 2017; Shielder et al., 2018; Tiseo, Foo, Veluvolu, & Tech, 2018). Alterations to the proprioceptive system will increase reliance on the visual and vestibular system. Because the proprioceptive system detects external stimuli, alterations to the system cause more prominent balance deficits. Damages to the proprioceptive system impair the ability to detect changes in the surface stability, temperature, incline, decline, and depth of steps (Hong, Park, Kwon, Kim & Koo, 2014; Tiseo, Foo, Veluvolu, & Tech, 2018; Westcott et al., 1997).

Footwear

Footwear plays a vital role in the maintenance of postural control and balance. Characteristics that influence postural control include shaft height, outsole and midsole hardness, heel height and mass (Chander, Morris, Wilson, Garner, & Wade, 2016). Previous literature notes that footwear has been identified as a potential risk factor for lower extremity injury, specifically injury at the ankle (Aquino, Amasay, Shapiro, Kuo & Ambegaonkar, 2019). The knowledge that footwear choice may predispose an individual for risk of injury calls for further examination of the aforementioned design characteristics before choosing a sports shoe. Cheerleading footwear design has focused on low mass and cushioning for shock absorption but because of the desire of athletes to have the least amount of added mass when performing, the shock absorption aspect of the variety of shoes is minimal (Wu & Chiang, 2004). Additionally, slip resistant rubber outsoles are traditionally added to cheer shoes. This combination of characteristics has been shown to influence range of motion, ground reaction force attenuation and subtalar joint adaptability (Simpson, DeBusk, Hill, Knight & Chander, 2018; Wu & Chiang, 2004). Footwear research has primarily focused on running shoes, but the findings can be translated over to other sports. Researchers note that a decrease in the shock absorption properties change ankle kinematics. Specifically, changes in outsole and midsole hardness are the main source of these kinematic differences, noting that ankle inversion and plantar flexion are increased as hardness decreases (Hardin et al., 2004). Little is known regarding how the structural integrity of cheer shoes changes throughout a season and how this affects lower extremity biomechanics. However, research notes that decrements in postural control and lower extremity mechanics are affected with other types of athletic footwear. A recent study examined “new” and “dead” pointe shoes in professional ballet dancers, focusing on ballet specific skills and muscle activities in the lower extremities. Researchers found that the “dead” shoes displayed an increase in muscle activity and postural sway, noting that the wear and tear of pointe shoes may put professional dancers at a risk of lower extremity injury (Aquino, Amasay, Shapiro, Kuo & Ambegaonkar, 2019; Kong, Candelaria & Smith, 2009). Noting that the wear and tear of ballet shoes can place a dancer at greater risk of ankle injury encourages researchers to further analyze the differences between “old” and “new” shoes in other sports. Collegiate cheerleaders will wear one pair of shoes from August to May, which is the length of an entire season. Understanding that footwear can increase the risk of lower extremity injury and the “wear” and “tear” of performing may also add to the risk of injury calls for further investigation into the differences between “Old” and “New” cheer shoes.

APPENDIX C: ADDITIONAL METHODS

Participant Demographics	Participant ID: ______________________
Age (years)	
Mass (kg)	
Height (cm)	
Gender	
Shoe size	
Sport Position	
Socks worn during testing	
"New" shoe style	
"Old" shoe style	
"Old" shoe age (training hours)	
Socks worn during testing	
Limb Dominance	

Shoe Age Guide	Participant ID: ____________________
Yes / No	Are the shoes you will be wearing your current season's shoes?
#: _____	If no, how many seasons have you worn them?
#: _____	How many weeks have you worn these shoes?
#: _____	How many football games did you wear these shoes?
#: _____	How many basketball games did you wear these shoes?
Yes / No	Did you compete at NCA College Nationals in these shoes?
Additional hours #: _____	If you have worn these shoes for any other training time or game time, specific to cheerleading, please elaborate in the box below by explaining what was done in the time worn

Shoe Age Calculation

Shoe Age=(Number of Football Games Cheered * 4 hours) + (Number of Basketball Games Cheered * 2 hours) + (9 hours of practice per week * Number of weeks worn) + (Number of NCA Competitions worn * 5 hours) + (Number of additional training hours worn)

APPENDIX D: ABBREVIATIONS

1. FGBS - Firm Ground Bilateral Stance
2. FPBS - Foam Pad Bilateral Stance
3. FGDL - Firm Ground Dominant Leg
4. FPDL - Foam Pad Dominant Leg
5. FGNL - Firm Ground Non-Dominant Leg
6. FPNL - Foam Pad Non-Dominant Leg
7. FGHS - Firm Ground Heel Stretch
8. FPHS - Foam Pad Heel Stretch
9. FGA - Firm Ground Arabesque
10. FPA - Foam Pad Arabesque
11. SDP – Step-Down Platform
12. SDT – Step-Down Tilted

APPENDIX E: IRB DOCUMENTS

Institutional Review Board (IRB)

Application for Research Approval – Expedited/Full Board

Compliance Information
Please indicate which of the following will be used in your research: (applications may be submitted simultaneously)
☒ Human Subjects ☐ Care and Use of Vertebrate Animals (Submit IACUC Application) ☐ Biohazards (Submit IBC Application)
Please indicate if the following are included in the study (Check all that apply):
☐ Survey delivered by email to .georgiasouthern.edu addresses ☐ Deception ☐ Prisoners ☐ Children ☐ Individuals with impaired decision making capacity, or economically or educationally disadvantaged persons ☐ Video or Audio Recordings ☐ Human Subjects Incentives ☒ Medical Procedures, including exercise, administering drugs/dietary supplements, and other procedures, or ingestion of any substance
Is your project a research study in which one or more human subjects are prospectively assigned to one or more interventions (which may include placebo or other control) to evaluate the effects of those interventions on health-related biomedical or behavioral outcomes. See the IRB FAQ for help with the definition above. ☐ Yes ☒ No If yes, attach Good Clinical Practice (GCP) CITI training appropriate to the project.

Instructions: Please respond to the following as clearly as possible. The application should include a step by step plan of how you will obtain your subjects, conduct the research, and analyze the data. Make sure the application clearly explains aspects of the methodology that provide protections for your human subjects. Your application should be written to be read and understood by a general audience who does not have prior knowledge of your research and by committee members who may not be expert in your specific field of research. Your reviewers will only have the information you provide in your application. Explain any technical terms, jargon or acronyms.

1. Personnel
Please list any individuals who will be conducting research on this study. Also, please detail the experience, level of involvement in the process, and the access to information that each may have.
Experience with force plates, balance testing - Abigail Johnson (primary investigator, access to all information), Dr. Jessica Mutchler (investigator, access to all information), Andrew Crawford (investigator, access to all information), Kelsey Lewis (investigator, access to all information), Dr. Li Li (investigator, access to all information), Joshua Pascal (investigator,access to all information), Savannah McLain (investigator, access to all information) Experience with force plates, balance testing, and step down task - Dr. Samuel J. Wilson(co-primary investigator, access to all information)

2. Purpose
A. *Briefly describe in one or two sentences the purpose of your research.*
The aim of this study is to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step down tasks in " old " and "new" cheer shoes.
B. *What questions are you trying to answer in this project? Please include your research question in this section. The jurisdiction of the IRB requires that we ensure the appropriateness of research. It is unethical to put participants at risk without the possibility of sound scientific result. For this reason, you should be very clear about how participants and others will benefit from knowledge gained in this project.*
1. Are balance and postural sway affected by the age of the shoe worn by participants? 2. How does the age of the shoe worn by participants alter landing mechanics during single leg drop landings? Participants will not directly benefit from this study. However, the findings will add to the exsisting literature regarding, cheerleading, balance, and footwear.
C. *Provide a brief description of how this study fits into the current literature. Have the research procedures been used before? How were similar risks controlled for and documented in the literature? Have your instruments been validated with this audience? Include citations in the description. Do not include dissertation or thesis chapters.*
Cheerleading participation is growing at a rate of 18% per year in the United States. Athletes are starting to participate in cheerleading as young as the age of 5.[9, 10] Overall, in all age groups of cheerleading, the leading mechanism of injury is due to falls (29.4%), and sprains and strains are the most common types of injuries sustained, accounting for 53% of all injuries. Further, the most commonly injured joint is the ankle joint, accounting for 44.9% of all injuries, specifically involving damage to the lateral ligaments of the ankle, and result from injuries with the ankle in a plantar-flexed position.[6] Lateral ankle sprains, which damage the lateral ankle ligaments result from excessive subtalar inversion or a combination of subtalar inversion, internal rotation, and talocrural plantar flexion about an externally rotated distal tibia during ground contact. Landing from a jump requires ankle plantar flexion and in some cases ankle inversion to attenuate large and rapid loads when landing, which can initiate the mechanism of a lateral ankle sprain. The rapid and unexpected joint perturbations that

Institutional Review Board (IRB)

Application for Research Approval – Expedited/Full Board

can occur when landing can generate large supination moments of the ankle complex that can result in damage to the lateral ankle ligaments. 13 An important contributor to fall risk is the control of posture. Postural control involves many different underlying physiological systems such as visual acuity, somatosensory and vestibular function. Alterations to any of these systems may result in balance decrements, and increased fall risk. 15 Because footwear serves as the interface between the human foot and the external environment, it plays a vital role in the maintenance of postural control, and balance. 3 Standard footwear characteristics that influence postural control are footwear mass, shaft height, sole/midsole hardness, and heel height. Cheerleading specific footwear is designed to have a low mass, slip resistant rubber soles, and EVA foam midsoles to provide cushioning and shock absorption. Previous research has shown that these characteristics influence subtalar joint adaptability, range of motion, and ground reaction force attenuation capabilities. Furthermore, these design characteristics have been attributed to reductions in postural stability, and somatosensory and proprioceptive feedback from cutaneous receptors of the foot/ankle. 15 Although evidence regarding changes in the structural integrity of cheerleading specific shoes and how they effect lower extremity biomechanics is limited, decrements in postural control, and lower extremity mechanics have been reported in other types of athletic footwear. Early work on footwear biomechanics suggests that runners should change their running shoes every 300-400 miles to accommodate for decreases of shock absorption properties. It was further reported that the main changes observed in response to the increased "milage" or use of the running shoe is at the ankle. 1 More recent work examined the effects of "new" compared to "dead" pointe shoes in professional ballet dancers. Suggesting lower extremity biomechanics were altered between footwear conditions. Specifically, it was observed that the "dead" pointe shoes decreased balance during ballet specific skills, as well as increased muscle activity of the lower extremities. This suggests that the wear and tear of the pointe shoes may increase lower extremity injury risk in dancers. 1 Limited information is available regarding the effects of cheerleading specific footwear on balance and lower extremity biomechanics during landing, or how continued "wear and tear" of cheer shoe smay alter these effects.. Therefore, the aim of this study is to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step down tasks in " old " and "new" cheer shoes.

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3. Outcome

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Please state what results you expect to achieve. Who will benefit from this study? How will the participants benefit (if at all)? Remember that the participants do not necessarily have to benefit directly. The results of your study may have broadly stated outcomes for a large number of people or society in general.
The expected results are as follows: 1. Balance performance will be decreased with " old " shoes than with "new" shoes 2. Risk of injury will be higher with " old " shoes than with "new" shoes Results will provide an addition to the preexisting research and literature regarding cheerleading, sporting shoes, and balance.

4. Describe Your Subjects
A. Maximum number of participants
34
B. Briefly describe the study population.
34 collegiate cheerleaders between the ages of 18 - 25
C. Applicable inclusion or exclusion requirements (ages, gender requirements, allergies, etc.)
Inclusion criteria: collegiate cheerleaders (18-25 years old), enrolled in academic courses at Georgia Southern, one new & one old pair of personal cheer shoes that fit the classification criteria, no history of a lower extremity fracture, surgery, or ankle sprain within the last 3 months, free of neurological or musculoskeletal disease or disorder, no current concussion, participate in a moderate amount of physical activity (150 min. or more of moderate exercise/week or 75 min. or more of vigorous exercise/week), not allergic to adhesive Exclusion criteria: any injury to ankle in the last 3 months that hinders participation, no shoes that fit the classification criteria, lack of physical activity participation, any neurological or musculoskeletal disease or disorder, current concussion, allergic to adhesive
D. How long will each subject be involved in the project? (Number of occasions and duration)
This study will run from November to December 2019. Testing will consist of three sessions in the Biomechanics Lab at Georgia Southern University. Day one will consist of roughly 30 minutes of paperwork and familiarization, Day two and three will both consist of 60-minute experimental testing in randomized footwear conditions.

5. Recruitment
Describe how subjects will be recruited. (Attach a copy of recruitment emails, flyers, social media posts, etc.) DO NOT state that subjects will not be recruited.
With approval from the head coach, participants will be recruited during practice time without the head coach present during recruitment

6. Incentives
A. Are you compensating your subjects with money, course credit, extra credit, or other incentives? ☐ Yes ☒ No
B. *If yes, indicate how much and how they will be distributed.*
C. *Describe if and how you will compensate subjects who withdraw from the project before it ends and any exclusion criteria from compensation.*
Not applicable

7. Research Procedures and Timeline
A. Outline step-by-step what will happen to participants in this study (including what kind of experimental manipulations you will use, what kinds of questions or recording of behavior you will use, the location of these interactions). Focus on the interactions you will have with the human subjects. Specify tasks given as attachments to this document.
The testing procedures that will be used in this study are similar to activities performed on a regular basis. The participants will not be completing any tasks that will put them at an additional risk of injury as the tasks included are designed to mimic movements that are completed. For further clarification on the application to sport, examples of movements being mimicked will be included in the explanation of each task. Testing will consist of three sessions. Day one will consist of 30 min. of paperwork and familiarization, Day two & three will both consist of 60- min experimental testing in randomized footwear conditions Prior to testing, the protocol will be thoroughly explained to the participant. Once all questions have been satisfactorily answered, each participant will be asked to sign informed consent. General demographics, physical activity level information, anthropometric assessment and physical activity readiness questionnaire (PAR-Q) will be obtained about each participant. Researchers will record individual age, height, weight, and foot arch height. Moreover, participants will complete the Foot and Ankle Disability Index (FADI) and the Foot and Ankle Disability Index-Sport (FADI-S) questionnaires to determine ankle sprain and ankle instability history. The experimental procedures will include measurements of ground reaction force, and 3D motion capture using an AMTI OR6 Series Force Platform (1000Hz, AMTI, Watertown, MA, USA), Vicon Motion Capture software (Vicon Motion Ltd., Version 1.8.5, Oxford, England) will be

Institutional Review Board (IRB)

Application for Research Approval – Expedited/Full Board

used to record each trial throughout testing protocol. 3D motion capture will be used to assess changes in body movement such as joint angles and linear and angular velocity. The 3D motion capture software that will be used in this study (Vicon Motion Ltd., Version 1.8.5, Oxford, England) builds a skeletal model of the participant's lower extremity and participants cannot be physically identified by the videos. During the familiarization session, participants will be allowed to practice the step-down task onto the flat surface as many times as desired. All participants will be restricted from visually seeing the inverted platform that will be used in the study during the familiarization session. However, participants will be made aware, both verbally and in the written consent document, that the inversion platform will be used in the experimental session. Marker sets will placed on the participants' lower extremities (back, thighs, shins, and feet) on top of their athletic clothing (t-shirt and leggings).

Balance Testing:
At each data collection point, participants will complete standing balance tests consisting of three 20 s trials for each condition. Testing conditions are as follows: Firm Ground (FG) Bilateral Stance, Foam Pad (FP) Bilateral Stance, FG Unilateral Dominant Leg, FP Unilateral Dominant Leg FG Unilateral Non-Dominant Leg, FP Unilateral Non-Domimant Leg, FG Heel Stretch, FP Heel Stretch, FG Arabesque and FP Arabesque. Trials will be randomized for each participant. During testing, participants will be instructed to stand as still as possible. Balance testing will be used to mimic flyers balancing in the air during a stunt and balancing after jumping and tumbling.

Step Down Task:
The protocol for this task was adapted from a previous study. [1] Following completion of participant set-up, participants will be asked to complete five trials of a normal step down from a height of 60 cm. to a flat surface placed 30 cm. below and then take an additional step to the ground. This task is very much like walking down a flight of stairs. There will be one minute of rest between each of these five trials. After completion of the five normal step down trials, participants will face away from the testing area for 60 seconds in which they will listen to music being played on noise-cancellation headphones to take away the knowledge of the subsequent landing on either the flat surface or the inverted surface. During the next ten trials, a flat or tilted platform (25 degrees) will be placed below the 60 cm. box so the participants are unaware of the surface (flat or tilted) that they will be stepping on. The angle of 25 degrees was chosen based on previous literature for participant safety as ankle sprains are suggested to occur when the subtalar joint exceeds 35 degrees of inversion. For additional participant safety, grip tape will be administered to the top of the force platform to ensure that the participants' foot does not slip during the step-down task. The unexpected step down surface is needed to properly analyze the corrective responses. If participants were made aware of the surface they were stepping down on, the anticipatory response can confound biomechanical analyses.[1] Between each of the ten total trials, if the participant steps down onto a flat surface they will once again turn away from the testing area and listen to music on noise-cancellation headphones for 60 seconds before completing the next trial. One of the ten trials will be randomly selected by the investigators to place the tilted surface below the 60 cm. box so that the inversion perturbation is unexpected to the participants. Step down tasks will be used to mimic stepping off of a stunt and landing safely after tumbling and jumping. To ensure participant safety, the individuals will be asked to step up on to the initial platform. Spotters will be present during the entire testing period. Lastly, participants will complete 5 trials of double leg landings onto the flat platform adhering to the same protocol.

References:

1. Simpson, J, et al, "Lower-Extremity Kinematics During Ankle Inversion Purterbations: A Novel Experimental Protocol That Stimulates an Unexpected Lateral Ankle Sprain Mechanism", *J Sport Rehab*, 2018

B. *Identify any activity included in the research description that will occur without modification regardless of the research effort. (E.g., A class exercise that is part of the normal course activities that is not altered for the research about which you will collect data or a team warm-up exercise session that is not altered for the study about which you will collect data.)*

N/A

C. *Describe how legally effective informed consent will be obtained. Attach a copy of the consent form(s).*

Once all questions have been satisfactorily answered, informed consent will be obtained from each participant in order to participate.

D. *If minors are to be used describe procedures used to gain consent of their parent (s), guardian (s), or legal representative (s), and gain assent of the minor.*

☒ N/A or Explain:

E. *Describe all study instruments and whether they are validated. Attach copies of questionnaires, surveys, and/or interview questions used, labeled accordingly.*

All participants will fill out the informed consent. All participants will fill out PAR-Q and ankle stability questionnaires. The aforementioned forms are attached. It is important that all forms are filled out to ensure that proper understanding of testing protocol is understood.

F. *Describe how you will protect the privacy of study participants.*

After forms are completed forms will be filed and secured in a locked filing cabinet in Dr. Samuel Wilson's office. Only authorized personnel will have access to the locked cabinet Additionally, participants will be coded using first and last initial followed by a number (i.e. AJ1) to ensure the privacy of names and personal information.

8. Data Analysis

A. *Briefly describe how you will analyze and report the collected data.*

Institutional Review Board (IRB)

Application for Research Approval – Expedited/Full Board

Postural Sway Measures:
The ten conditions on the force platform use participant's center of pressure to quantify postural sway. The dependent variables of interest are the sway velocity components in the medial-lateral (M/L) and anterior-posterior (A/P) directions, and root mean square (RMS) of COP displacement in the AP and ML directions. Sway velocity (cm/s), is a measure of the change of the COP per unit time, where the value is representative of changes in the location of the COP in the M/L and A/P directions. Higher values indicate decreased postural stability, as they imply larger position changes of the COP. Previous research has identified sway velocity as an appropriate dependent measure for use in determining postural stability (Wade et al., 2004). RMS (cm) denotes a measure for mean body sway of a specific period of time and a comparison to be made between conditions. Variables of interest will be collected for both "new" and "old" footwear conditions.

Step Down Task Measures:

Lower extremity movement and forces during the step down task will be calculated using Vicon Nexus software. Specifically, ankle, knee, and hip movement will be analyzed at each discrete time point from 150 ms pre-initial contact (IC) to 150 ms post-IC for each landing trial. This 300-ms time window was chosen to be analyzed as prior case studies have shown that lateral ankle sprains can occur within the first 150 ms of initial ground contact. IC will be identified when the vertical component of the ground reaction force exceeds 15 N. Maximum ankle inversion velocity and maximum inversion angle, measured in degrees per second and degrees, respectively, will be defined as the maximum velocity and maximum inversion angle during the 150-ms post-IC period. Step down tasks will be performed in both "new" and "old" footwear conditions.

Statistical Analyses:

Descriptive and dependent variables will be reported as mean and standard deviation. Dependent-samples 2-tailed *t* tests will be used to analyze postural sway measures between "new" and "old" footwear conditions. A 2 x 2 (footwear [New vs Dead] x condition [flat vs inverted] repeated measures analysis of variance will be used to analyze time-averaged ankle, knee, and hip movementat each discrete time point from 150 ms pre-IC to 150 ms post-IC. Cohen's *(d)* effect size data will be calculated for the postural control dependent measures and evaluated as small ($d < 0.40$), medium ($d = 0.40 – 0.80$), or large ($d > 0.80$), while partial eta squared will be calculated for measures of effect size within the repeated measures anovas for step down measures. All statistical analyses will be performed using SPSS, with an a priori alpha level of $p < 0.05$.

B. *What will you do with the results of your study (e.g. contributing to generalizable knowledge, publishing sharing at a conference, etc.)?*

The results of this study will contribute to the existing literature on cheerleading, sporting shoes, ankle sprains and balance. Additionally, researchers will look to present the findings at future conference proceedings, and publish in academic journals.

C. *Include an explanation of how will the data be maintained after the study is complete. Specify where and how it will be stored (room number, password protected file, etc.)*

All forms and participants' data will be stored on Georgia Southern University's Campus, in a locked filing cabinet in Dr. Samuel J. Wilson's office for 5 years following the termination of the study

D. *Student researchers must specify which faculty or staff member will be responsible for records after you have left the university.*

Dr. Samuel J. Wilson will be responsible for study records upon my graduation.

E. *Anticipated destruction date or method used to render data anonymous for future use.*

☐ *Destroyed 3 Years after conclusion of research (minimum required for all PIs)*
☒ *Other timeframe (min 3 years): 5 years*
☐ *Maintained for future use in a de-identified fashion. Method used to render it anonymous for future use:*
Note: Your data may be subject to other retention regulations (i.e. American Psychology Association, etc.)

Special Conditions

9. Risk

Even minor discomfort in answering questions on a survey may pose some risk to subjects. Carefully consider how the subjects will react and address ANY potential risks.

A. *Is there greater than minimal risk from physical, mental, or social discomfort?*

☒ No
If no, Do not simply state that no risk exists. If risk is no greater than risk associated with daily life experiences, state risk in these terms.

Institutional Review Board (IRB)

Application for Research Approval – Expedited/Full Board

The investigators have developed the experimental protocol to minimize the risks associated with participation in the study procedures. In this study, participants will step down 30.48 cm onto an inversion platform set at 25 degrees of inversion to simulate the lateral ankle sprain (LAS) mechanism. Previous research has utilized tilt platforms to study ankle sprain mechanics that were much greater than the 25 degrees we have chosen to use (Fu et al., 2014; Ha et al., 2015). Moreover, in many studies participants have been required to complete jump-landings on a tilted surface from heights at or above 30.48 cm (Fu et al., 2014; Gutierrez et al., 2010; Theodorakos et al., 2016). Lateral ankle sprains are not likely to occur until the foot/ankle exceeds 35 degrees of inversion (Fong et al., 2009; Kristianslund et al., 2011). Although participants will not have knowledge of the surface (flat or tilted) they are stepping onto during the unexpected trial, we have chosen to utilize an angle for the tilt platform (25 degrees) and a drop height (30.48 cm) that is much more safe and conservative than previously published studies. In addition, the 25 degrees of inversion using a tilted platform device from a height of 30.48 cm to simulate LAS mechanics has previously been used by Dr. Sam Wilson and his protocol blinded the participants from knowing what surface was being stepped onto (Simpson et al., 2018). Participants will also understand that there is an inherent risk of injury associated with the testing procedures.

The investigators will make every effort make the risks known to the participants during the familiarization trial and all data collection sessions will be closed to all individuals not involved in testing procedures. Non-approved personnel who are not part of the submitted IRB application will be prohibited from observing the study procedures. These may include, but not limited to, other graduate or undergraduate students within the department. Only IRB approved personnel who are listed on the application and who have successfully completed the CITI human subjects training will be in contact with the participant and have access to the collected data. Additionally, spotters will be present to assist you if you do lose your balance when stepping down.

References:
Fong, D. T. P., Hong, Y., Shima, Y., Krosshaug, T., Yung, P. S. H., & Chan, K. M. (2009). Biomechanics of supination ankle sprain. The American Journal of Sports Medicine, 37(4), 822-827.
Fu, W., Fang, Y., Liu, Y., & Hou, J. (2014). The effect of high-top and low-top shoes on ankle inversion kinematics and muscle activation in landing on a tilted surface. Journal of Foot and Ankle Research, 7(1), 14.
Gutierrez, G. M., & Kaminski, T. (2010). A novel dynamic ankle-supinating device. Journal of Applied Biomechanics, 26(1), 114-121.
Ha, S. C. W., Fong, D. T. P., & Chan, K. M. (2015). Review of ankle inversion sprain simulators in the biomechanics laboratory. Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology, 2(4), 114-121.
Kristianslund, E., Bahr, R., & Krosshaug, T. (2011). Kinematics and kinetics of an accidental lateral ankle sprain. Journal of Biomechanics, 44(14), 2576-2578.
Theodorakos, I., Rueterbories, J., Lund, M. E., Andersen, M. S., de Zee, M., & Kersting, U. G. (2016). Ankle bracing effects on knee and hip mechanics during landing on inclined surfaces. International Biomechanics, 3(1), 22-32.
Simpson, J. D., Stewart, E. M., Rendos, N. K., Cosio-Lima, L., Wilson, S. J., Macias, D. M., ... & Knight, A. C. (2019). Anticipating ankle inversion perturbations during a single-leg drop landing alters ankle joint and impact kinetics. *Human movement science*, *66*, 22-30.

☐ Yes

If yes, describe the risks and the steps taken to minimize them. Justify the risk undertaken by outlining any benefits that might result from the study, both on a participant and societal level.

B. Will you be carrying out procedures or asking questions that might disturb your subjects emotionally or produce stress or anxiety? If yes, describe your plans for providing appropriate resources for subjects.

No

10. Research Involving Minors
A. Will minors be involved in your research? ☐ Yes ☒ No
B. *If yes, describe how the details of your study will be communicated to parents/guardians. Please provide both parental consent letters and child assent letters (or processes for children too young to read).*

Institutional Review Board (IRB)

Application for Research Approval – Expedited/Full Board

C.	*Will the research take part in a school (elementary, middle, or high school)?* ☐ Yes ☒ No
D.	*If yes, describe how permission will be obtained from school officials/teachers, and indicate whether the study will be a part of the normal curriculum/school process.*
	☐ Part of the normal curriculum/school process ☐ Not part of the normal curriculum/school process

11. Deception	
A.	*Will you use deception in your research?* ☒ No Deception ☐ Passive Deception ☐ Active Deception
B.	*If yes, describe the deception and how the subject will be debriefed. Include a copy of any debriefing materials. Make sure the debriefing process is listed in your timeline in the Procedures section.*
C.	*Address the rationale for using deception.*
Be sure to review the deception disclaimer language required in the informed consent. Note: All research in which active deception will be used is required to be reviewed by the full Institutional Review Board. Passive deception may receive expedited review.	

12. Medical Procedures	
A.	Does your research procedures involve any of the following procedures: ☒ Low expenditures of physical effort unlikely to lead to physical injury ☐ High expenditures of physical effort that could lead to physical injury ☐ Ingesting, injecting, or absorbing any substances into the body or through the skin ☐ Inserting any objects into bodies through orifices or otherwise ☐ Handling of blood or other bodily fluids ☐ Other Medical Procedures ☐ No Medical Procedures Involved
B.	*Describe your procedures, including safeguards. If appropriate, briefly describe the necessity for employing a medical procedure in this study. Be sure to review the medical disclaimer language required in the informed consent.*
Trained, non-physician exercise specialists certified in CPR, basic life support, and exercise testing will supervise participants undergoing testing. All participants will be instructed to report any unexpected problems or adverse events they may encounter during the course of the study to study personnel. Medical care is available in the event of injury and can be provided by Health Services at (912) 478-5641 or the participant may seek care from another medical provider. If a medical emergency were to occur during testing, the Georgia Southern University's Emergency Action Plan will be activated, and EMS called. The action plan is as follows: 1) Call 911 if participant is unconscious or needs immediate medical attention (e.g., chest pain, acute severe musculoskeletal injury). Explain to the dispatcher what has occurred and what assistance is needed. If needed, use of the automated external defibrillator (AED) which is located in the laboratories where the research will be conducted if the emergency is of a cardiac origin; 2) CPR being performed by the investigators in the absence of the AED or until it arrives; and 3) Follow up with the participant in person the same day to confirm the physical condition/status of the participant.	
C.	*Describe a medical emergency plan if the research involves any physical risk beyond the most minimal kind. The medical research plan should include, but not necessarily be limited to: emergency equipment appropriate for the risks involved, first rescuer actions to address the most likely physical risk of the protocol, further actions necessary for the likely risks.*

Reminder: No research can be undertaken until your proposal has been approved by the IRB.

WATERS COLLEGE OF HEALTH PROFESSIONS

DEPARTMENT OF HEALTH SCIENCES AND KINESIOLOGY

Informed Consent
Biomechanical Comparison of "Old" and "New" Cheer Shoes in Collegiate Cheerleaders.

You are being invited to participate in the **Biomechanical Comparison of "Old" and "New" Cheer Shoes in Female Collegiate Cheerleaders** study. The primary investigator is Abigail Johnson and is currently a masters student at Georgia Southern University. The purpose of this study is to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step-down tasks in "Old" and "new" cheer shoes.

You are being invited to participate in this study because you are an adult 18-25 years of age, and meet all the following criteria: you are a collegiate cheerleader, enrolled in an academic course at Georgia Southern, have no history of a lower extremity fracture, surgery, or ankle sprain within the last 3 months, free from any neurological or musculoskeletal disease or disorder, do not have a concussion, you participate in a moderate amount of physical activity each week (150 minutes or more of moderate exercise a week or 75 minutes or more of vigorous exercise per week), you are not allergic to any adhesive. After reporting to the Biomechanics Laboratory, you will be asked to complete the Functional Ankle Instability Index (FADI), the Functional Ankle Instability Index-Sport (FADI-Sport), and the physical activity questionnaire. These questionnaires will be given to make sure that you do not have any ankle instability, pain, or any other musculoskeletal or neurological disorder. After completing the questionnaires, you will have the chance to read and ask questions about this consent document and the study procedures. After signing the consent document, your height and weight will be measured by the researchers, and then you will be allowed to practice the step down task that you will perform during the study. This visit should take approximately 30 minutes to complete.

The second and third day you will be asked to report back to the Biomechanics Laboratory. You will be asked to wear athletic clothing (t-shirt and athletic leggings). Upon arriving at the Biomechanics Laboratory, you will be prepared for testing. Special marker sets (clusters) will be placed on your lower body. These will be placed over your clothing and not attached directly to your skin. The clusters will be placed on your lower back, both of your thighs, both of your shins, and the top of both of your feet. The markers will be secured to your body using a non-adhesive athletic wrap. The purpose of these markers are to track your body movements with the special cameras that are in the lab. This will allow us to create a virtual skeleton of your body and measure your different movements during the study. Nobody will be able to identify you from your motion capture trials, it only displays a general model of the skeletal system with no identifying features. Once the reflective markers are placed on you, the researchers will ask you to stand in the center of the room. A researcher will use a wand like device to point to different bony landmarks and your joints, such as your hip, knee, and ankle so the motion capture system can recognize the specific body parts of your lower body. You will be asked to stand still for about one or two minutes.

The next step in the study is to complete balance testing. You will be asked to stand in several different positions, with the instructions "stand as still as possible". The positions include standing on both feet, standing on only your dominant foot, standing on only your non-dominant foot, standing and performing a heel stretch, and standing and performing an Arabesque. Each of these stances will be done on solid ground, and on a foam pad to provide an unstable condition. Each standing position will be performed 3 times, for 20 seconds each.

Next, you will be asked to stand on a 60 cm high box and wear dribbling practice glasses so you won't be able to see your feet. You will be asked to place the foot of your dominant leg out in front of the box, balancing on your non-dominant leg. When instructed, you will step down off the box a height of 30 cm, landing on the force platform with your dominant leg, and then you will take an additional 30 cm step down from the force platform onto the ground with your non-dominant leg. The task is similar to walking down two stairs. The force platform will be placed on either a flat surface or a surface that is rotated 25 degrees with respect to the ground. In both conditions, the center of the force platform will be 30 cm above the ground and 30 cm below the top of the box you are standing on. The first 5 trials you will step down onto the force platform located on the flat surface. You will be given one minute of rest between each of these five trials. After the first five trials, you will be given noise cancelling headphones to wear and will face away from the experimental setup. During the next 10 trials, you will step down onto the force platform on the flat surface, but during one of the trials, we will switch the flat platform with the platform rotated 25 degrees with respect to the ground without your knowledge. Lastly, you will complete 5 trials of stepping down on two feet following the same instructions. You will only be landing on the flat platform for these trials.

The potential risk assumed during the testing is no greater than the risk associated with normal activities of daily living and cheerleading practice. However, balance testing and step down tasks do provide their own, minimal risk of the participant falling. The distance you are required to step down is fairly small, but it is possible to sustain an injury such as an ankle sprain during the step down task. Spotters will be present to assist you if you do lose your balance when stepping down, and you will be allowed to practice the step down task onto the force platform on the flat surface during both days prior to data collection. You understand that medical care is available in the event of injury resulting from research but that neither financial compensation nor free medical treatment is provided. Should medical care be required, you may contact Health Services at (912) 478-5641.

You understand that there are no direct benefits to the participant for participating in this study. The study will have a total of three sessions: 1) familiarization and health screening session (30 minutes) 2) two testing session (60 minutes). The total time of commitment for the study will be 150 minutes.

Informed consent and PAR-Q forms will be maintained in a locked file cabinet located in the Faculty Advisor's office for 5 years following the termination of the study. Coded data from this study may be placed in a publicly available repository for study validation and further research. You will not be identified by name in the data set or any reports using information obtained from this study, and your confidentiality as a participant in this study will remain secure. In certain conditions, it is our ethical responsibility to report situations of child or elder abuse, child or elder neglect, or any life-threatening situation to appropriate authorities. However, we are not seeking this type of information in our study nor will you be asked questions about these issues.

Your participation in this study is completely voluntary and you may end your participation at any time by telling the primary investigator, Abigail Johnson. You understand that you do not have to answer any questions that you do not want to answer. You may withdraw from the study at any time and without penalty. The investigator may in her absolute discretion terminate the investigation at any time.

If you have questions about this study, please contact Abigail Johnson at (912) 667 - 8646 or the researcher's faculty advisor, Dr. Samuel Wilson at (912) 478 - 2117. For questions concerning your rights as a research participant, contact Georgia Southern University Office of Research Services and Sponsored Programs at 912-478-5465 and/or irb@georgiasouthern.edu. If you consent to participate in this research study and to the terms above, please sign our name and indicate the date below

You will be given a copy of this consent form to keep for your records. This project has been reviewed and approved by the GSU Institutional Review Board under tracking number H20089.

Principal Investigator
Abigail Johnson
(912) 667 - 8646
aj04712@georgiasouthern.edu

Faculty Advisor
Dr. Samuel Wilson
2117A Hollis Building
(912) 478 - 2117
sjwilson@georgiasouthern.edu

__________________________________ ____________________
Participant Signature Date

I, the undersigned, verify that the above informed consent procedure has been followed.

______________________________ ____________________
Investigator Signature Date

www.orthopaedicscores.com

Date of completion
July 19, 2019

The Foot & Ankle Disability Index (FADI) Score - Sports Module

Clinician's name (or ref) ________________________ **Patient's name (or ref** ________________________

Please answer every question with one response that most closely describes your condition within the past week. If the activity in question is limited by something other than your foot or ankle, mark N/A

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
1. Running	○	○	○	○	○
2. Jumping	○	○	○	○	○
3. Landing	○	○	○	○	○
4. Squatting and stopping quickly	○	○	○	○	○
5. Cutting, lateral movements	○	○	○	○	○
6. Low-impact activities	○	○	○	○	○
7. Ability to perform activity with your normal technique	○	○	○	○	○
8. Ability to participate in your desired sport as long as you would like	○	○	○	○	○

Thank you very much for completing all the questions in this questionnaire.

The Foot & Ankle Disability Index (FADI) Score is 0

Print page   Close Window   Reset

To save this data please print or Save As CSV

Nb: This page cannot be saved due to patient data protection so please print the filled in form before closing the window.

Reference for Score:
Martin RL, Burdett RG, Irrgang JJ. Development of the Foot and Ankle Disability Index (FADI) J Orthop Sports Phys Ther. 1999;29:A32–A33

www.orthopaedicscores.com

The Foot & Ankle Disability Index (FADI) Score

Date of completion
July 19, 2019

Clinician's name (or ref) ____________

Patient's name (or ref ____________

Please answer every question with one response that most closely describes your condition within the past week. If the activity in question is limited by something other than your foot or ankle, mark N/A

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
1. Standing					
2. Walking on even ground					
3. Walking on even ground without shoes					
4. Walking up hills					
5. Walking down hills					
6. Going up stairs					
7. Going down stairs					
8. Walking on uneven ground					
9. Stepping up and down curves					
10. Squatting					
11. Sleeping					
12. Coming up to your toes					
13. Walking initially					
14. Walking 5 minutes or less					
15. Walking approximately 10 minutes					
16. Walking 15 minutes or greater					
17. Home responsibilities					
18. Activities of daily living					
19. Personal care					
20. Light to moderate work (standing, walking)					
21. Heavy work (push/pulling, climbing, carrying)					
22. Recreational activities					

	NO PAIN	MILD	MODERATE	SEVERE	UNBEARABLE
23. General level of pain					
24. Pain at rest					
25. Pain during your normal activity					
26. Pain first thing in the morning					

Thank you very much for completing all the questions in this questionnaire.

Print page | Close Window | Reset

The Foot & Ankle Disability Index (FADI) Score is 0

To save this data please print or Save As CSV

Nb: This page cannot be saved due to patient data protection so please print the filled in form before closing the window.

(**NB.** A FADI score may not be calculated if there are greater than 3 missing items.)

There is one further small section to this score. This is optional. Just click below to select

SPORTS MODULE

Reference for Score:
Martin RL, Burdett RG, Irrgang JJ. Development of the Foot and Ankle Disability Index (FADI) J Orthop Sports Phys Ther. 1999; 29: A32-A33

2019 PAR-Q
The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or No	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition☐ **OR** high blood pressure☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? (Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:**________	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition: **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:**________	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? (Please answer **NO** if you had a problem in the past, but it does not limit your current ability to be physically active). **PLEASE LIST CONDITION(S) HERE:**________	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered YES to any of the questions above, you will be excluded from this study.

WATERS COLLEGE OF HEALTH PROFESSIONS

DEPARTMENT OF HEALTH SCIENCES AND KINESIOLOGY

Recruitment Script
Biomechanics Comparison of "Old" and "New" Cheer Shoes in Collegiate Cheerleaders.

You are being invited to participate in the **Biomechanical Comparison of "Old" and "New" Cheer Shoes in Collegiate Cheerleaders** study. The primary investigator is Abigail Johnson and is currently a masters student at Georgia Southern University. The purpose of this study is to examine the biomechanical differences exhibited by collegiate cheerleaders while performing balance testing and step-down tasks in "old" and "new" cheer shoes. You are being invited to participate in this study because you are a current collegiate cheerleader who has no current injury that is preventing you from participating in practices. The investigators of this study are looking at how new and old cheerleading shoes affects the way you balance and land during tests that will mimic movements you regularly perform at practices, gameday and competition. If you are interested in participating in this study, please reach out to Abigail Johnson via email at aj04712@georgiasouthern.edu or by phone at 912-667-8646.