GROUND REACTION FORCES IN BALLET: DIFFERENCES ACCORDING TO FOOTWEAR AND JUMP CONDITIONS

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ABSTRACT

The purpose of this investigation was: 1) to investigate the maximal ground reaction force (GRF) when ballet dancers land from two jump conditions in pointe shoes, flat technique shoes, and barefoot; and 2) to explore if particular pointe shoe characteristics (e.g. shoe age, shank style) have an effect on the GRF of these jump landings. Twenty-one healthy, female college ballet majors (19.28 ± 1.01 yrs; 167.45 ± 4.39 cm; 52.75 ± 3.43 kg) from an elite program volunteered for this study. Two jump conditions were studied, these included an assemblé jump (a jump from one foot to two feet) and a grand jeté jump (a large jump from one foot to the other foot.) Three shoe conditions were studied; these included barefoot, flat technique shoes, and pointe shoes. Each dancer performed three assemblé jumps in each shoe condition, and three grand jeté jumps in each shoe condition, landing onto a recessed force plate. Vertical jump height and horizontal jump distance were also analyzed through video recording and Dartfish Version 6 software (Dartfish, Alpharetta, Georgia, USA). Order of jump and shoe condition trials were counterbalanced. Peak GRF (N) was measured and recorded. The subjects also completed a health history questionnaire and a ballet shoe questionnaire. The health history questionnaire contained questions regarding general health status, activity, and previous injury history, and the shoe questionnaire included information concerning specifics of the pointe and flat technique shoes used. Means and standard deviations of GRF were calculated for each trial. Separate repeated measures analysis of variance were calculated for each dependent variable. Each had two within subjects factors: shoe type, at three levels; and jump type, at two levels. One-way analyses of variance were performed on the specific pointe shoe characteristic data. Tukey post hoc test was completed on significant findings. For all calculations, the alpha level was set at a priori of $p<0.05$. Results of the statistical analysis revealed no significant differences

in GRF between the shoe conditions ($F_{2,20}$=1.94, p=0.16, ηp^2=0.08, power=0.32), however, we did find a difference in GRF between jump types ($F_{1,20}$=5.85, p=0.02). Post-hoc testing revealed that the grand jeté jump condition produced significantly higher GRF than the assemblé jump condition (mean difference=239.28N, 95% CI=32.95N to 445.62N). Analysis of point shoe characteristics revealed that neither shoe age [Assemblé ($F_{1,20}$=0.005, p=0.944); Grand Jeté ($F_{1,20}$=1.908, p=0.183)] nor shank style [Assemblé ($F_{1,20}$=0.058, p=0.812); Grand Jeté ($F_{1,20}$=1.596, p=0.222)] had any impact on GRF in either jump condition. Results of this study indicate that GRF varies between ballet jumps, with the grand jeté jump having higher GRF values than the assemblé jump; however, it does not appear that shoe condition significantly affects GRF during functional ballet movements. Overall, the results of this study indicate that shoe conditions do not have a significant impact on a dancer's ground reaction force.

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INTRODUCTION

Dancers are athletic artists who experience consistently high rates of injuries. Up to 67% to 95% of dancers will develop at least one injury on an annual basis.[1-3] Chronic lower extremity injuries are the most common category of injuries amongst classical ballet dancers, and can include tendinopathies, stress fractures, ankle impingement syndromes, and patellofemoral syndrome.[4,5] While there has been much research on the types of injuries incurred by dancers, there has been little exploration as to why these injures occur. There are many factors that may influence injury rates, such as training regime, lack of rest,[6] mentality regarding injury recovery[1-3], floor and stage conditions,[7,8] and forces absorbed by the body while dancing.[9,10]

Specifically, ground reaction forces (GRF) can have detrimental effects on the body, and can be the result of poor dancing surfaces[7], poor technique[11], or type of footwear utilized. Exploring these factors, such as poor dancing surfaces, is important when attempting to develop preventative measures. Dancing surfaces have greatly improved over the last decade, however they are still an important consideration for the dancer and instructor. Newer "sprung" flooring reduces the impact of ground reaction force transmitted to the dancers body.[7] When landing on nonresillent, hard flooring, the dancer's body must absorb more force, increasing the risk of injury.[7] Poor technique also increases a dancers susceptibility to injury. The use of proper jumping technique has been emphasized in the literature in order to decrease undesired biomechanical forces, but most dance instruction focuses on take off mechanics when jumping.[12,13] Emphasizing proper landing technique instead may help decrease the effects of GRF on the body. Proper landing technique includes initial contact of the toes with the floor, contact of the ball of the foot with the floor, progressive lowering of the foot to a flat position, and finally single heel contact.[13] Double heel strike has been noted to be poor technique and a

possible cause for increased GRF and therefore potentially increased risk for injury.[12,14] Finally, the choice of dancer's footwear has received minimal attention, but may also significantly affect GRF.

Ballet footwear has been long thought of to be a detriment to dancers' health. There are two main shoe types worn by classical ballet dancers: the flat technique shoe and the pointe shoe. The flat technique shoe design is a basic slipper constructed of leather or canvas, which uses elastics to conform the shoe to the foot. It lacks any real support for the dancer's foot. The pointe shoe is a harder shoe covered in corset satin. Its toe box consists of layers of cardboard, burlap, and paper soaked with glue and other adhesives to cause hardening. The shank is formed from leather and/or cardboard and helps provide stiffness to the foot.[15]

Dancers will wear through pointe shoes quickly, and are also known to spend extensive amounts of time modifying the shoes before wearing them. They may purposely break the shank, jump on top of the toe box, slam the shoe in a door, or even bash it with a hammer to soften it before beginning to dance in the shoe.[16] Many professional dancers use numerous pairs of shoes a week during heavy performance times, and can even use multiple pairs during a single performance. Most advanced dancers will need a new pair of pointe shoes at least every 1-2 weeks.[16]

In addition to the two traditional types of footwear, ballet dancers have more recently been known to take portions of class in barefoot. The importance of cross-training and varying conditioning methods has begun to be emphasized in dancers' health, and this has brought about some usage of barefoot conditions.[17,18] For example, many dancers will perform Pilates or "floor barre" as an alternative to taking typical class.[19] Previous studies have explored GRF in pointe shoes and flat technique shoes, but none have explored this barefoot condition.[12,13,20] Also,

previous studies have not considered any "breaking in" treatments applied to the pointe shoes involved, the pointe shoe age, or any padding added by the dancer to the shoe while participating in the study.[12,13,20]

Therefore, the purpose of this investigation is: 1) to investigate the maximal ground reaction force (GRF) when ballet dancers land from two jump conditions in pointe shoes, in flat technique shoes, and in barefoot; and 2) to explore the effects that specific pointe shoe characteristics (e.g. shoe age, shank style) may have on GRF.

METHODS

Subjects

Twenty-one female volunteers were recruited from the Indiana University Ballet program (age=19.28 ± 1.00, weight= 52.74 ± 3.43 kg, height = 167.45 ± 4.38 cm.) Subjects had trained in classical ballet for 12.85 ± 2.37 years, and had danced 15.02 ± 7.49 hours during the week when tested. Thirty-three percent had current, chronic musculoskeletal complaints. These included primarily tendinopathies of the ankle and knee, chronic ankle instability, and overuse syndromes. Volunteers were excluded if they had a history of acute lower extremity injury within the past six weeks, lower extremity surgery within the past eight weeks, or if they were experiencing any acute illness at the time of testing. All subjects read and signed an informed consent form before participating in the study. Both the consent form and the study were approved by the University's Institutional Review Board for the Protection of Human Subjects.

Instrumentation

To measure the GRFs, a standard, recessed force plate (AMTI Accugait System Model ACG, Watertown, Massachusetts) was used. The force plate has been shown to be both highly

valid and highly reliable in measuring ground reaction forces.[14,21] The force plate is commonly the criterion reference used in studies.[14,21-23] To store and analyze the force plate data, an HP desktop computer (Hewlett-Packard, 2009) was used with BioAnalysis software (AMTI BioAnalysis, Watertown, Massachusetts.) Additionally, Dartfish Version 6 software (Dartfish, Alpharetta, Georgia, USA) was used to analyze video imaging for jump height and jump distance. Dartfish has been shown to be a reliable instrument in measuring human motion, though there has been little research performed on the software.[24] To acquire and store video imaging, one video camera (Sony Electronics Inc., San Diego, CA) was used.

Procedures

Laboratory Set-Up

A recessed force plate with a 2.5m long runway aligned with the edges of the force plate was used for data collection. The video camera was used to evaluate vertical jump height and horizontal jump distance. It was positioned to the side of the force plate, parallel to the runway, 3.5m away from the force plate and 1.4m from the floor.

Laboratory Procedure

All subjects reported to the Athletic Training Research Laboratory for one testing session. Each session lasted approximately one hour. At the beginning of each session, the subject completed a health history questionnaire, which covered exclusion criteria and demographic information. Potential subjects were excluded if they had a history of acute lower extremity injury within the last six weeks, if they had a history of lower extremity surgery within the last eight weeks, or if they were experiencing any acute illness. In addition to the health history questionnaire, they also completed a questionnaire regarding their ballet history and their

dance footwear usage. Each dancer performed a 10-minute ballet warm-up of choice in flat technique shoes.

After the warm-up, we instructed the dancer to adjust their tights so that the waistband sat parallel to the floor, and to not move the tights during the testing procedures. This was in order to provide a reference mark for measurements in the Dartfish software. The jumps that were performed included the classical ballet assemblé jump (Figure 1) and the grand jeté jump (Figure 2). The dancers were allowed to attempt each jump condition in each shoe condition until they were comfortable with the procedures.

In order to perform both the practice trials and the test trials for the assemble jump, the dancer was instructed to begin in a tendu en avant from fifth position on a diagonal from the force plate. They were then instructed to step onto their front foot, to begin the assemble on the opposite leg, to land onto the center of the force plate, and to hold their balance for approximately two to three seconds before stepping off of the force plate.

For the grand jeté, the dancer was instructed to center their feet at the beginning of the runway, in a classical fifth position, with their foot of preference in front. They were then instructed to approach the force plate down the runway in a typical sequence seen during grand allegro: tombé, pas de bourée, glissade, grand jeté. They were asked to land the grand jeté onto the center of the force plate to their best ability, but were instructed to step through the jump once they had landed.

After the dancer felt comfortable with the runway, jump, and landing procedure and had finished her practice trials, she performed three trials of each jump in three shoe conditions – barefoot, flat technique shoe, and pointe shoe. The orders of both the jumps and the shoe conditions were randomized for each dancer. We voided any trial in which the dancer did not

land on the force plate directly from the jump or had any other visible jump error until there were a total of three measurable trials for each condition. The dancer was allowed to rest in-between each trial as long as desired. Maximal and peak GRFs were recorded through the force plate connected to the desktop computer. Additionally, the video imaging from the video camera was collected and uploaded to the computer for jump height and jump distance analysis.

Video Analysis

The recorded video was then analyzed for jump height and horizontal jump distance utilizing Dartfish software. The horizontal jump distance was marked from the initial point of the waistband reference where the take-off leg had maximal knee flexion, to the point of initial foot contact on the force plate. The vertical jump height was measured from the waistband reference when the take-off leg had maximal knee flexion to the highest point of the jump determined by frame-by-frame analysis.

Shoe Questionnaire

Each dancer also completed a shoe questionnaire (Table 1) that was used to determine more specific characteristics related to their pointe shoes, such as breaking-in and padding treatments. Large amounts of descriptive data were collected in order to produce a broad perspective of a ballet dancer's shoe usage, shoe preparation, attitudes towards their shoes, and their dance and injury histories.

Statistical Analysis

The mean GRF_{max} (Newtons), mean vertical jump height (cm), and mean horizontal jump distance (cm) were used for statistical analysis. Means and standard deviations were calculated for each jump condition in each shoe condition. Separate repeated measures analyses of variance were calculated for each dependent variable. Each has two within subjects factors: shoe type, at three levels, and jump type, at two levels. Additionally, one-way analyses of variance were

performed on the specific pointe shoe characteristic data after GRF was standardized to body weight. One comparison evaluated differences in GRF between the two shank styles (full shank and modified shank) and the second comparison evaluated differences in GRF between two different shoe ages (0-7 days and 8-14 days). Tukey post hoc testing was completed on significant findings. For all calculations, the alpha level was set at a priori of $p<0.05$.

RESULTS

Means and standard deviations of maximal GRF and vertical jump height for all shoe and jump conditions are displayed in Table 2. For GRF, no significant jump by shoe interaction was identified ($F_{1,20}=0.18$, $p=0.77$, $\eta_p^2=0.01$, power=0.07). Additionally, no significant differences between shoe conditions were found ($F_{2,20}=1.94$, $p=0.16$, $\eta_p^2=0.08$, power=0.32). There was a significant difference in GRF between jump conditions ($F_{1,20}=5.85$, $p=0.02$, $\eta_p^2=0.08$, power=0.63), with the grand jeté jump condition having a significantly higher GRF than the assemblé condition (mean difference=239.28N, 95% CI=32.95 to 445.62N).

Jump height and jump distance analysis revealed no significant differences between the three shoe conditions (jump height: $F_{1,20}=2.14$, $p=0.13$, $\eta_p^2=0.40$, power=0.37; jump distance: $F_{1,20}=0.09$, $p=0.99$, $\eta_p^2=0.01$, power=0.05). However differences were identified between the two jump conditions (jump height: $F_{1,20}=22.66$, $p=0.01$, $\eta_p^2=0.30$, power=0.99; jump distance: $F_{1,20}=31.52$, $p=0.01$, $\eta_p^2=0.37$, power=1.00). Jump distance was longer in the grand jeté (mean difference=0.41m) and jump height was higher in the assemblé (mean difference=0.02m).

Analysis of pointe shoe characteristics revealed that neither shoe age [assemblé ($F_{1,20}=0.005$, $p=0.944$); grand jeté ($F_{1,20}=1.908$, $p=0.183$)] nor shank style [assemblé

($F_{1,20}$=0.058, p=0.812); grand jeté ($F_{1,20}$=1.596, p=0.222)] had any impact on GRF in either jump condition.

DISCUSSION

The purpose of this investigation was twofold: to determine if a difference in GRF exists in ballet jumps landings in different shoe conditions; and to determine if particular pointe shoe characteristics (e.g. shoe age, shank style) have an effect on the GRF during these jump landings. Our results demonstrated no significant differences in GRF among the three types of shoe conditions used in this study. Additionally, the various pointe shoe conditions that we investigated also did not have a major impact on GRF.

GRF is of interest due to its potential correlation with increased injury rates.[7,13,15] Limited previous literature demonstrates differences in GRF when comparing different types of ballet footwear used;[13] however, no previous studies have investigated more functional ballet movement.[12,13,20] The results of this study refuted the hypothesis that GRF would be significantly lower in pointe shoes than when in flat shoes or barefoot.

These footwear hypotheses were based on prior research primarily by Walter et al[13], as well as somewhat by Chockley et al[12]. Walter et al.[13] demonstrated a significant decrease in GRF when performing assemblé in pointe shoes when compared to flat shoes. Chockley et al.[12] showed decreased GRF when landing en pointe versus landing on the full foot in pointe shoes.[12]

In comparison to Walter et al.[13], the current study utilized more functional ballet movement. This readily explains the difference in results. Walter et al.[13] used a highly controlled assemblé condition. While one desires a high level of control in the experimental setting, this may not produce an accurate representation of the forces encountered daily by dancers in the studio and on-stage. We instructed dancers to perform the most natural (according

to their training and technique) movement possible. While previous studies[13,20] may have demonstrated a significant difference in GRF when a strictly controlled assemblé jump is performed, this study demonstrated no significant difference when a dancer performed jumps similar to how she would in a typical ballet class.

In addition to the previous lack of research on true functional ballet movement, no previous studies had investigated shoe characteristics (e.g. age, shank condition, brand, etc.) in conjunction with GRF. One study conducted by Cunningham et al.[25] investigated the in vitro effects of mechanical compression on pointe shoes to quantify ultimate compressive strength and stiffness based on brand. They found significantly higher resistance to cyclical fatigue in Gaynor Minden shoes, higher axial compressive stiffness in Leo shoes, significantly lower axial compressive strength in Freed shoes, and significantly higher vertical compressive stiffness in Freed shoes.[25]

The Gaynor Minden shoe differs significantly from the traditional pointe shoe due to its materials design. [16,25,27] These shoes are made up of an elastomeric resin toe box and shank, and a "sound and shock absorbing panel of high-density urethane foam."[16] There were only two dancers who initially volunteered for this study who wore this type of pointe shoe. One of these dancers left the department before she could schedule a testing session, and the second dancer experienced scheduling conflicts. However, it should be noted that both dancers claimed switching to Gaynor Minden shoes because of repeated stress fractures, and have not since had any significant bony stress injury.

Of the dancers that participated in our study, seventeen dancers utilized Freed pointe shoes, 3 dancers used Bloch shoes, and 1 dancer used Suffolk shoes. This also brings to light the complication of teacher preference in shoe type, as well as deals or sponsorships that pointe shoe

companies may develop with particular ballet companies. While subjects in this study were not required to wear any particular shoe within their ballet department, nor were there any sponsorships or shoe rooms provided, there was an obvious preference towards the Freed brand. No concrete reasons were given for this preference for Freed in the shoe questionnaire; rather, this trend appears to be a result of the interplay of various factors, including vamp shape, box shape, shank style, durability, and cost. Shoe preferences have proven to be very individualized to each dancer, yet are influenced by teacher preference and opinion. One subject, for example, had changed her pointe shoe type three times over the school year without satisfaction, due primarily to teachers disagreeing with the appearance of the shoes on her feet. She was not willing to attempt Freed shoes because she felt that they were not supple enough for her feet, but was willing to try various other brands that were not her previous preference.

Cunningham et al.'s study[25] gathered data on new, unaltered pointe shoes. While effective in the laboratory, it would be unusual to encounter a dancer using shoes in this state. Due to the amount of alteration that a typical dancer may perform to their shoe, it is of importance to investigate these potential factors. It has been long noted anecdotally that dancers performing in "dead" (i.e. old) pointe shoes will encounter injuries more frequently. Research is needed to determine if this is due to the sheer activity that the dancer is performing, or to a potential lack of support and absorptive nature of the shoes utilized. Based on our current study, we did not find that the age of the shoe had an impact on GRF. The average age of shoes utilized was 6.9 days.

In addition to shoe age, we also collected data on many other pointe shoe conditions. Data collected on breaking-in strategies was too varied to allow us to conduct statistical analysis on these strategies. We were also interested in investigating the differences in GRF based on the

type of padding that a dancer used in her pointe shoes (if any at all). Miller et al.[26] investigated experimental modifications to flat technique shoes utilizing traditional orthotic materials such as Spenco and Sorbathane, and showed no reduction in force. But no study to date has investigated padding alterations to the pointe shoe, particularly those alterations that the dancer has chosen to use herself, outside of the experimental setting. Unfortunately, there was also too much variance in this data to perform statistical analysis. Two other areas that we were interested in investigating were the level of the dancer (e.g. corps, soloist, principal) and any history of bony stress injury. Neither of these demonstrated data able to be statistically analyzed. With a larger subject population, this would likely be better elucidated. Additionally, by adding populations with less training or who are younger and still developing, differences in GRF may be more pronounced.

Limitations

There were several limitations in this study. We would have liked to control the pointe shoe conditions (including brand, age, padding used, etc.) and observe how that affects GRF in the same dancer's jumps. However, ballet dancers are exceedingly particular about what shoes they wear and how these shoes are prepared.[16,26] It would have been difficult to get subjects to comply with this type of protocol. Additionally, it would be cost prohibitive with each pair costing anywhere from $60-$90 on average.

Despite drawing subjects from a small, discrete, and elite population, technique and motor control strategies were also varied. Because of this, there was moderate variation between trials, which could have affected the results. Additionally, the dancers were not accustomed to aiming for a discrete landing target, such as our force plate. The force plate target may have contributed to less natural movement or hesitation to full jumps.

Areas of Future Research

Research concerning both GRF and shoe conditions in ballet warrant further investigation. There are several specific areas where this type of research may benefit the dance community. First, higher control of experimental conditions is needed. In this study, we allowed the dancers to use a current pair of pointe shoes for the pointe shoe condition. While it may be difficult to convince dancers to jump or dance in shoes they do not choose themselves, this would allow further research control of the types of pointe shoes used. The exact amount of usage of the pointe shoes before the experiment, and any type of breaking-in treatments performed on the shoes would also be beneficial to evaluate. These factors may prove critical to influencing GRF.

While shoe conditions may be more easily controlled as research progresses, jump strategies and technique should be controlled as well, despite the greater complexity. Advanced biomechanical analysis of ballet movements and GRF analysis need to be integrated. Researchers may then be able to delineate which particular styles or attributes of jumps may increase GRF, and therefore dancers may be able to avoid or reduce these in order to reduce GRF.

Finally, research should focus on further supporting the possible causative nature of high amounts of GRF to injury. Once a link can be further established, efforts aimed at reducing GRF may prove easier as the dance community realizes the importance of these efforts.

CONCLUSION

Results of this study demonstrated no significant differences in GRF between barefoot, flat technique shoe, and pointe shoe conditions, nor were there any significant differences in

GRF revealed when pointe shoe age and shank style characteristics were analyzed. While this is in contrast with limited previous literature[13], we conclude that utilizing a jump style more typical of a daily ballet class produced more applicable results. Based on these results, we encourage the dance and research communities to focus more on the protocol of technique utilized when jumping rather than the shoe conditions used. While there may be biomechanical concerns associated with footwear, this study does not support the need to change footwear conditions based on GRF.

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TABLE 1: **Pointe Shoe Questionnaire**

1) What brand of pointe shoes are you wearing today? (e.g. Freed, Bloch, etc.)

2) What type of pointe shoes are you wearing today? (e.g. Studio II, Sonata, etc.)

3) What size of pointe shoes are you wearing today?

4) Age of this pair of pointe shoes:

5) What type of flat technique shoe are you wearing today?

6) Age of this pair of flat technique shoes:

7) Is the shank a full shank, or ¾ shank? Full 3/4

Is the shank broken? Yes No

8) Do you request a specific maker currently? Yes No

If yes, what maker(s) do you request?

9) Have you requested a specific maker in the past? Yes No

10) How much do you pay on average per pair for your current shoes?

11) Does cost influence your choice of pointe shoes? Yes No

12) Do you typically perform any type of breaking-in treatments to your shoes? Yes No

Did you apply this breaking-in treatment to the shoes that you're wearing today? Yes No

Please describe this breaking-in treatment:

13) Do you use any type of padding, tape, or treatments each time you wear your pointe shoes? Yes No

Are you wearing this type of padding/etc. today? Yes No

Please describe in as much detail as possible: (for instance, if using toe pads, give type or brand if possible) Also please use the diagram as needed to describe

14) How long have you worn your current *type* of pointe shoes?

15) Before changing to your current type(s) of pointe shoes, what were the previous *two* types of pointe shoes that you used?

16) Please choose your top 3 considerations in picking a type of pointe shoe:

Comfort Box/Platform Shape Vamp Shape Price Durability Fit Shank Style

17) Have you ever had a teacher not allow you to wear a particular brand or type of shoe? If so, what was their rationale (i.e. why did they tell you not to wear this particular type)?

18) How long does a pair of pointe shoes typically last you for class and rehearsal?

19) How long does a pair of pointe shoes typically last you for performance?

20) How many pairs of pointe shoes would you estimate that you use in a year?

21) How long does a pair of *flat* shoes typically last you?

22) How many years of classical ballet training do you have?

23) Have you ever had any orthopedic injury occur that was associated with changing type of pointe shoes?
Yes No

If yes, please describe:

24) If you were asked to perform a grand jeté, which would be your preferred front leg?

Right Left

25) What have been your roles in the last 3 major performances you've had at IU (or as many as applicable at IU)?

Last performance: Corps Soloist Principal/Pas

Second-to-last performance: Corps Soloist Principal/Pas

Third-to-last performance: Corps Soloist Principal/Pas

TABLE 2: Means and Standard Deviations for Each Condition

Shoe and Jump Condition	Maximal GRF (N)	Jump Height (cm)	Jump Distance (cm)
Barefoot Assemblé	1869.75 ± 391.54	37.9 ± 4.5	63.8 ± 18.6
Flat Assemblé	1814.46 ± 288.02	37.8 ± 4.6	61.5 ± 17.7
Pointe Assemblé	1719.21 ± 247.28	37.3 ± 3.5	62.3 ± 15.2
Barefoot Grand Jeté	2097.87 ± 525.49	31.0 ± 4.1	166.6 ± 19.8
Flat Grand Jeté	2042.91 ± 492.22	30.4 ± 4.3	169.3 ± 19.1
Pointe Grad Jeté	1970.20 ± 504.47	29.7 ± 4.1	168.5 ± 16.2

LEGEND OF FIGURES

Figure 1: Assemblé jump

Figure 2: Grand jeté jump

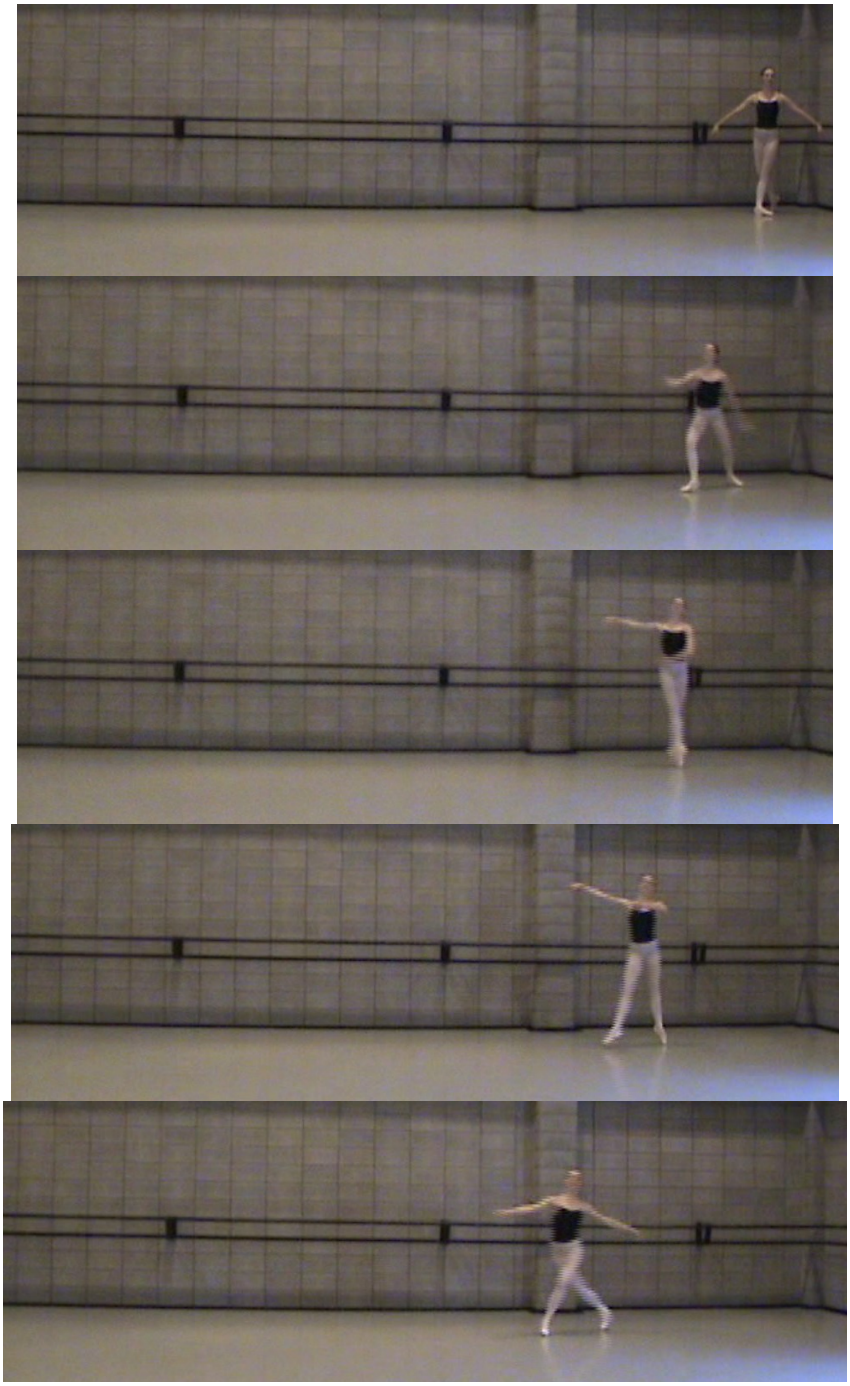
Figure 3: Barefoot condition, in fifth position

Figure 4: Flat technique shoe condition, in fifth position

Figure 5: Pointe shoe condition, in fifth position

FIGURE 1: Assemblé jump condition

FIGURE 2: Grand jeté jump condition



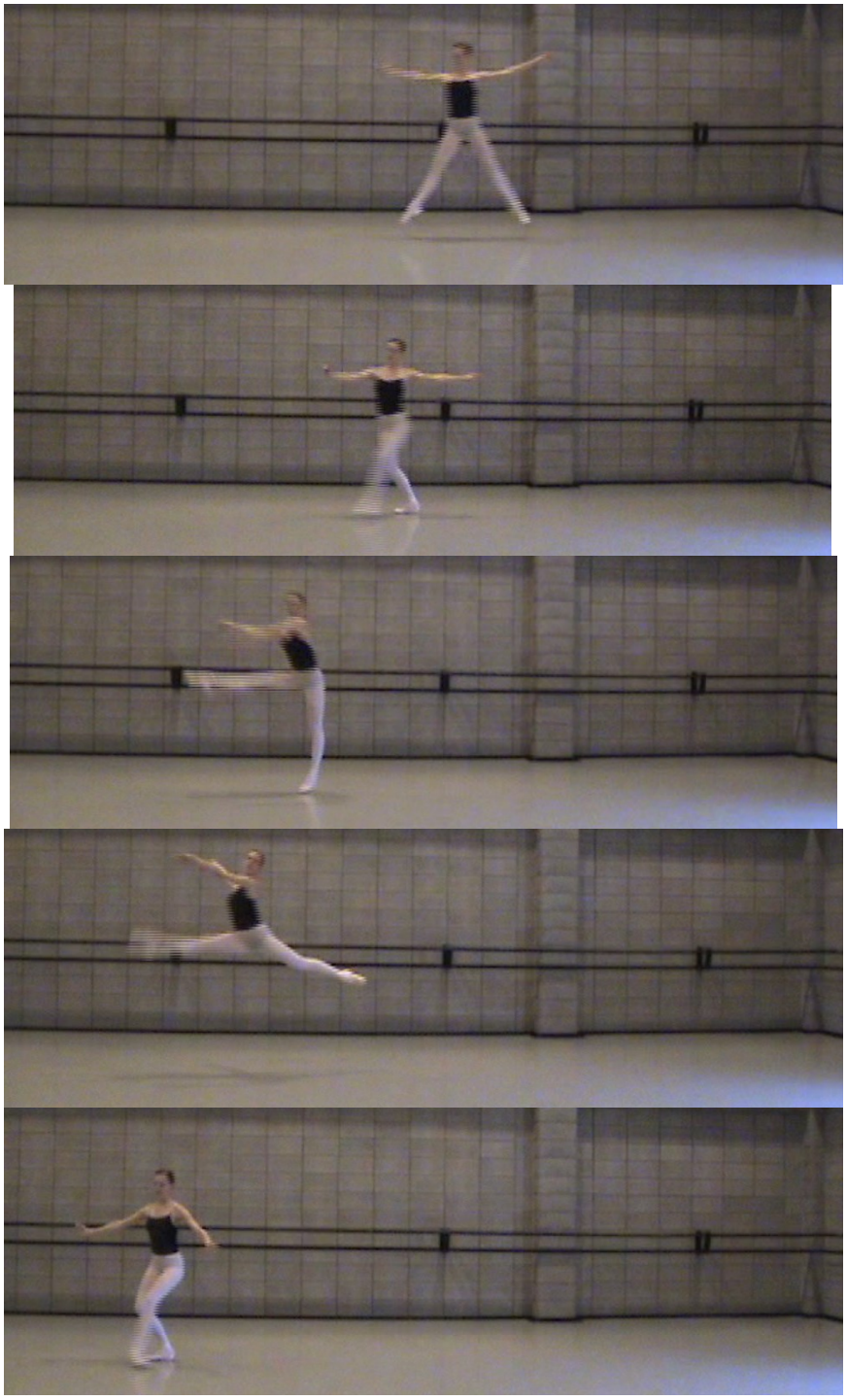


FIGURE 3: Barefoot condition, in fifth position

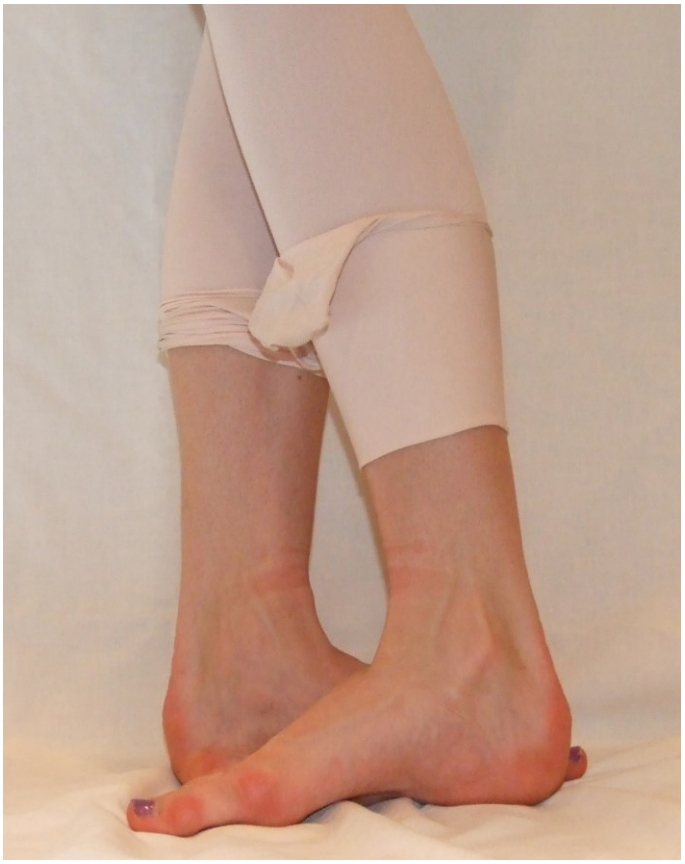
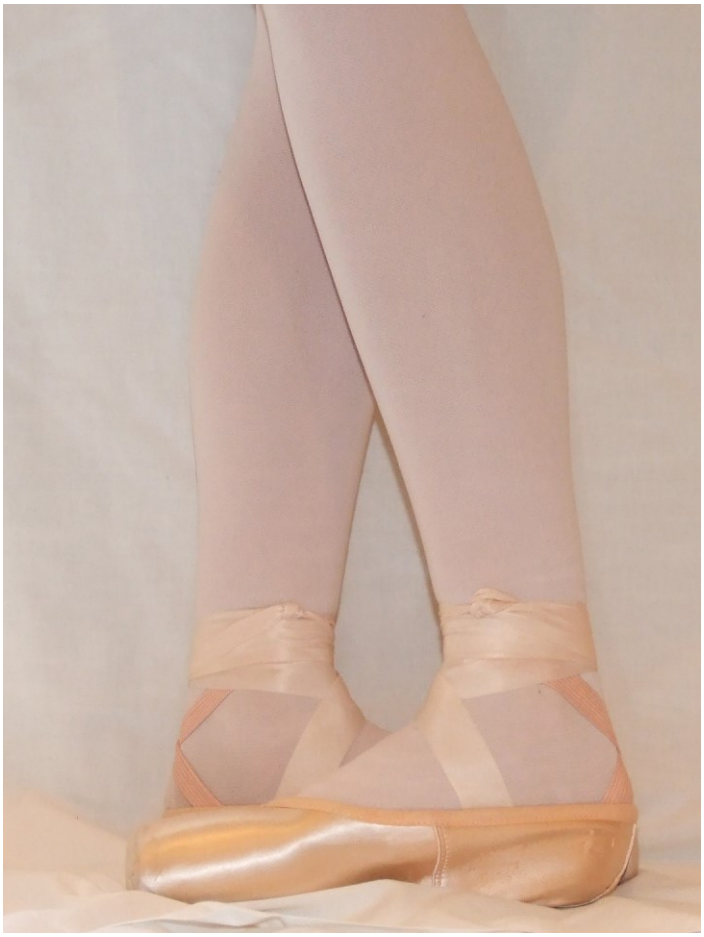


FIGURE 4: Flat technique shoe condition, in fifth position

FIGURE 5: Pointe shoe condition, in fifth position



APPENDICES

APPENDIX A

OPERATIONAL DEFINITIONS

ASSUMPTIONS

DELIMITATIONS

LIMITATIONS

STATEMENT OF THE PROBLEM

INDEPENDENT AND DEPENDENT VARIABLES

HYPOTHESIS

REFERENCE LIST

Operational Definitions

Acceptable Trials: The dancer lands on the force plate while maintaining correct technique (including an upright body position, hip external rotation, and toe-first landing.) Jumps landing with a double-heel strike will be counted as acceptable trials.

Assemblé: A ballet jump in which the dancer glides one foot along the ground, sweeps it into the air, and then pushes off the floor with the supporting leg, extending the toes and landing simultaneously in fifth position.

Grand Jété: A ballet jump from one foot to the other where the working leg is brushed into the air and both legs reach approximately 90° or higher, parallel to the floor.

Pointe Shoe: A ballet shoe made out of corset satin on the outside, and constructed of layers of various materials such as cardboard, paper, and burlap within the toe box, with a shank made of cardboard, leather, or other similar materials.

Flat technique shoe: A ballet shoe made of soft canvas or leather that conforms to the foot and is worn in ballet technique class.

"Breaking in" treatments: Any number of treatments that a dancer may apply to her pointe shoes before wearing them initially; these may include, pounding them with a hammer, smashing them in a door, wetting them, or other various methods.

Padding treatments: Any number of treatments that a dancer may apply to her feet or to the inside of her pointe shoe before dancing; these may include tape, toe spacers, paper towel, toe pads, or other various methods.

Ground reaction force: The body's reaction to the force that it exerts upon landing.

Landing position: Classical Russian ballet fifth position (feet are turned out and completely crossed so that the front foot touches the toe of the back foot and vice versa.)

Max amplitude: The maximum height that the dancer reaches during a jump while maintaining correct technique.

Demi pointe: The middle of the rise from flat foot to full en pointe position, when most of the weight is placed on the metatarsal heads.

Flat foot: When the entire plantar surface of the foot is in contact with the ground.

Turnout: External rotation at the hip, ideally at 90°, which aligns the feet in a straight 180° line opposite of each other. True turnout is not produced at the knee through tibial rotation.

Warm-up: 10 minutes of standardized classical ballet techniques intended to raise heart rate, increase blood flow to the extremities, and allow gentle stretching in order to prepare for more intense dancing. Performed at a ballet barre for support.

Assumptions

The following assumptions will apply to this study:

1. Subjects truthfully and accurately complete the medical history questionnaire.
2. Dancers have similar training backgrounds.
3. Dancers will follow directions.
4. Dancers will give maximal effort during jumps.
5. Dancers will not be fatigued before performing the study.
6. Dancers will not be affected by fatigue while performing the study.
7. All pointe shoe types used will be relatively similar.
8. All flat technique shoe types used will be relatively similar.
9. The force plate utilized is reliable and accurate.

Delimitations

The following delimitations will apply to this study:

1. Subjects will be recruited from the local university ballet major population.
2. Subjects will be 18-25 years of age.
3. Only two jump conditions will be studied.
4. Only three generic footwear conditions will be studied.
5. Subjects will be allowed to modify their pointe shoe footwear condition as they typically do for ballet class.
6. Subjects will have no history of acute lower extremity injury within the last six weeks.
7. Subjects will have no history of lower extremity surgery within the last eight weeks.
8. Three trials will be performed of each jump condition in each footwear condition, resulting in a total of 18 jumps per subject.
9. Dancers will be required to perform a minimum of three practice jump trials, but will be allowed to continue until they feel comfortable with the procedures.
10. Dancers will be allowed to rest as long as desired between trials.
11. Dartfish software will be used to analyze vertical jump height and horizontal jump distance.

Limitations

The following limitations apply to this study:

1. Pointe shoe brands, treatments, and intra-shoe padding cannot be controlled.
2. Sampling from a small group of 40 ballet dancers.

3. Only female dancers will be studied, due to the pointe shoe condition (males do not typically undertake dancing en pointe.)
4. Random selection is not possible as all subjects are volunteers.
5. Technique varies among dancers.
6. Many dancers have chronic musculoskeletal conditions of the lower extremity.

Statement of the Problem

Dance medicine literature has explored the great number of lower extremity injuries in ballet dancers, but little research has been done to determine why these injuries occur.[1-3] Many factors may affect injury types and rates among dancers, including floor surface, technique, and footwear type. A greater landing force may lead to the high rates of lower extremity injuries encountered by ballet dancers. Therefore, this study will investigate if the type of footwear increases ground reaction force during two ballet jumps. If the force is greater based on shoe or jump conditions, further studies can determine the relationship between increased force and rate of injury.

Independent Variables

Two independent variables will be evaluated in this study:

1. Shoe condition at three levels
    a. Pointe shoes
    b. Flat technique shoes
    c. Barefoot
2. Jump condition at two levels

a. Assemblé

b. Grand jété

Dependent Variables

Three dependent variables will be evaluated in this study:

1. Maximal ground reaction force in Newtons
2. Vertical jump height in meters
3. Horizontal jump distance in meters

Research Hypothesis

1. The GRF will be different in three shoe conditions, and the pointe shoe condition will produce the lowest GRFs.
2. The vertical jump height will be different when jumping in each shoe condition.
3. The horizontal jump distance will be different when jumping in each shoe condition.

Statistical Hypothesis

1. GRF $H_A : \mu_p \neq \mu_f \neq \mu_b$
2. Vertical jump height $H_A : \mu_p \neq \mu_f \neq \mu_b$
3. Horizontal jump distance $H_A : \mu_p \neq \mu_f \neq \mu_b$

Null Hypothesis

1. GRF $H_A : \mu_p = \mu_f = \mu_b$
2. Vertical jump height $H_A : \mu_p = \mu_f = \mu_b$
3. Horizontal jump distance $H_A : \mu_p = \mu_f = \mu_b$

APPENDIX B

REVIEW OF LITERATURE

REFERENCE LIST

REVIEW OF LITERATURE

Dance medicine research thus far has focused mainly on injury epidemiology, injury case studies, and relevant anatomy. The effects of various factors on injury relevance and prevention have only recently begun to be investigated. Research on ballet footwear, and its effect on biomechanics, has received minimal attention thus far, but impact the art extensively. This literature review will address: (1) injury prevalence and types of injuries seen in ballet; (2) types of footwear utilized in ballet; and (3) ground reaction forces in jumping.

Ballet Injury and Prevalence

Dancers are a unique blend of artist and athlete. This combination of roles makes injury assessment and treatment of dancers unique as well. Ballet dancers in particular suffer high incidence of injury, with reports of anywhere from 67% to 95% of dancers developing at least one injury on an annual basis.[1-3]

Injury incidence rates are difficult to calculate for dancers. There is no standard within dance medicine for defining injury, nor a typical way to collect exposure statistics.[27] Injury in dance is typically more chronic, and due to the nature of the ballet community in particular, dancers will rarely take any time off for injury.[1-3] Gauging incidence of injuries according to hours or numbers of exposure – as frequently seen in general sports medicine – can also be misleading when regarding professional dancers. The incidence of injury calculated in regards to exposure has been cited to be as high as 4.7 injuries/1000 hours, and as low as 0.77 injuries/1000 hours.[27,28] But the demands of specific choreography vary greatly, as do rehearsal and class schedules.[3] At times, some dancers may not have any rehearsals due to casting, while others may be dancing up to ten more hours a day.

Most injuries encountered by ballet dancers are chronic in nature and affect the lower extremity (57-75% of injuries), particularly the ankle and foot (34-54%).[1-5,27,29] Lateral ankle sprains are one of the most common injuries experienced by ballet dancers.[2,4,5,30] While these types of injuries may be fairly easily managed in many sports, with stabilization through taping or orthotics after an acute phase, the extreme range of plantarflexion necessary for pointe dancing requires longer time before returning to activity for most dancers.[31] The same twisting mechanism that can cause these inversion ankle sprains may also cause the common "dancer's fracture," or a spiral fracture of the fifth metatarsal neck.[4,5] Other injuries or syndromes frequently encountered by ballet dancers include: stress fractures, ankle impingement syndromes, os trigonum, flexor hallucis longus tendonopathy, hallux valgus, patellar and Achilles tendonopathies, seasmoditis, chondromalacia patellae, patellofemoral syndromes, snapping hip syndrome, and hip labral lesions.[4,5,29,30]

Stress fractures are particularly common among ballet dancers. Some studies show up to 45% of dancers reporting a history of stress fracture.[29] The first three metatarsals are common sites, and the second metatarsal in particular receives inordinate amounts of stress through loading of the en pointe position, and is one of the most common stress fractures seen.[5]

Injury is not only physically debilitating for a dancer, but also emotionally and financially taxing.[6] Most professional dancers are medically underserved and many lack appropriate medical insurance.[4] For passionate, professional dancers, injuries are not solely a threat to one's career or livelihood, but a threat to their very identity.[6] These psychological components can play a significant role in the healing and rehabilitation process. The dancer may see his or her body as equipment for the art.[6] This leads them to "push through" injury and normalize pain.[6,29] By normalizing pain, dancers begin to accept pain as a part their occupation and no longer

consider pain abnormal. By not allowing adequate time for rest or healing, due to either the sheer desire to be dancing or possible financial constraints of losing a position, dancers may prolong the healing process.

Ballet also has a history of rigid technique which appears to encourage these high injury rates.[4,5] Dancers demand actions out of their bodies unseen in other sports and occupations. Excessive hip, knee, and ankle external rotation through "turn-out"; large jumps; poor performance surfaces; dancing en pointe and painful footwear can all contribute to injury.[4,5,29] Furthermore, poor technique exacerbates potential risk for injury.[5]

High amounts of hip external rotation (HER) are greatly desired in classical ballet in order to produce the technique of turn-out, and this range of motion is typically determined within a few degrees by the age of 16-18.[4,5] Those dancers who do not possess large amounts of HER may "force" turn-out by altering and torque various joints along the lower extremity. These unfortunate alterations may include increased lumbar lordosis through anterior pelvic tilt, external rotation of the knee, and valgus heel/forefoot pronation.[5] Not only does poor technique cause an increased risk of injury, but even proper turn-out increases the incidence of patellofemoral tracking syndromes within ballet dancers, as it emphasizes lateral tracking.[5]

Other issues regarding technique include knee hyperextension and poor ankle range of motion. Genu recurvatum is a trait desired in ballet dancers.[5] It creates the "lines" that many choreographers desire within their pieces. It also, however, creates increased pressure and strain on the posterior knee capsule, and may be associated with injury to this area.[5] Poor ankle range of motion is a true detriment to the dancer performing en pointe. Without adequate plantarflexion in particular, a dancer may attempt to force this motion and cause greater stress on the already possibly pinched posterior ankle.[5] This can lead to the common posterior

impingement syndrome or even stress to the bones of the ankle. It may also cause the dancer to "sickle" their foot. "Sickling" is defined as a varus alignment of the foot which is undesired and will cause increased stress on the lateral aspect of the ankle.[5]

While poor technique may have a large impact on the high incidence of injury seen in ballet dancers, there are many other external factors to be considered as well. These can include negative work stress, poorly designed rehearsal and performance schedules, dance surfaces, and possibly most frequently, footwear.[3,5,7,8]

Ballet Footwear

The ballet pointe shoe has been cited as one common source contributing to injury to the foot and ankle.[4,5,16,26,29] The pointe shoe has changed little mechanically since the beginning of its use,[4] and overall modern pointe shoe design has been consistent since the 1950's.[13] Marie Taglioni is cited as being the first dancer to publically dance en pointe in 1832[25], but some reports cite the beginnings of pointe work in ballet all the way back to the 1600's.[4] Pointe shoes allow the dancer to rise fully onto the tips of toes, and produce the aesthetic of skimming and gliding across the floor.

While the pointe shoe is the typical shoe that a female ballet dancer wears, the flat ballet technique shoe is also utilized. This flat shoe is the typical "slipper" design that young dancers wear, before they are skeletally mature and strong enough for pointework.[23] These shoes are typically made of leather or canvas and use elastic to form-fit the foot. They can have a single leather or canvas sole, or a split-sole design.[16]

The pointe shoe is generally made up of a fairly rigid toe box, shank, and outer covering material. The toe box consists of many layers of cardboard, burlap, or even just paper, soaked

with glue and other adhesives to cause hardening. The shank is formed from leather and/or cardboard and helps provide stiffness to the foot.[25] Shanks come in full and three-quarter lengths, depending on dancer preference and need for stiffness versus flexibility. The outer covering material for pointe shoes is known as corset satin, a soft, cotton-backed cloth.[25] Both this cloth over the toe platform and the toe box in general wear out quickly with use and require continual replacement in the form of new shoes.[21,25] For some professional dancers, especially when performing in full-length ballets, it is not uncommon to use one to two pairs of pointe shoes for a show which are then unusable thereafter. Ballet companies have been reported to spend up to $60,000 on one ballerina's shoe budget per season, at elite professional levels.[4]

Not only do dancers wear through pairs of shoes quickly, they spend extensive amounts of time modifying these shoes before wearing them.[16,21,26] A common practice is for dancers to purposely break the shanks of their shoes in order to increase the flexibility of the shoe. Dancers may also jump on top of the toe box, slam it in doors, beat it on the floor, or even bash it with a hammer to soften it before beginning to dance.[16] The amount of breaking-in treatments performed to shoes lessens as a ballet dancer gains experience however. This suggests that either young dancers are selecting shoes too firm for them, or that more advanced dancers have the greater foot strength necessary to break their shoes in functionally while dancing.[16] In the study of GRFs, it is questionable whether a more supportive shoe potentially decreases GRF, and in the ballet world, breaking-in procedures could be correlated with a loss of stability or support of the shoe. Nevertheless, Wakes and Caudwell[16] found no relationship between injuries or discomfort and the type of breaking-in procedure used.

Dancers will also frequently outfit their pointe shoes with internal padding or treatments that are placed and replaced each time the shoe is put on. Common treatments include lambs

wool or gel toe pads to cover the tops of all toes, toe spacers, and wrapping each individual toe with tape or paper towel, among others.[16] Most of these are utilized to help prevent blisters and additional friction from the internal shoe rubbing against the skin.[21] It is common for the posterior heel of the shoe to rub the Achilles and irritate this tendon, especially if there is a history of tendonopathy.[16] The pointe shoe also has been found to create "dynamic positional hallux valgus" while en pointe. Most dancers suffer from at least moderate amounts of hallux valgus, and pointework will tend to exacerbate this.[26] Toe spacers are commonly used to realign the hallux with the first metatarsal and prevent lateral displacement while in the pointe shoe. However, any type of medical modification must be carefully considered with the dancer, as most ballet dancers are very particular about their shoe and foot modifications. Shoe brand type is also very particular among dancers. Initial pointe shoe fitting is a long process, and dancers will continue to experiment as they gain experience.[32] Being fit by an experienced, specialized sales person or dance instructor may make a large difference in the discomfort and injury incurred.

The materials utilized in pointe shoes are slowly beginning to advance. Moreover, the ability to analyze the shoes' strength and integrity is also developing. Cunningham[25] studied the static stiffness, static strength, and fatigue properties through cycles to failure of five major brands of pointe shoes. Out of Capezio, Freed, Gaynor Minden, Leo's, and Grishko brands, Leo's brand was the only shoe to demonstrate statistically significant difference in shoe stiffness. However, the Gaynor Minden showed significantly higher fatigue value (amount of cycles of force loading for the shoe to fail) ten times that of any other brand.[25] While this study was not a functional assessment of pointe shoes, it does demonstrate a large difference in the Gaynor Minden brand make-up. The Gaynor Minden shoe is made of a more technologically-advanced,

elastomeric resin toe box and a sound and shock-absorbing panel of high-density urethane foam at the platform of the shoe.[16] Further biomechanical analysis of this shoe could prove interesting results. It should be noted that anecdotally, many dancers do not like the feel of the Gaynor Minden shoe, and it may take a particular dancer to wear this type of pointe shoe.

While scientific pointe shoe analysis is growing, there is still little research on the topic of GRF in dance and particularly in ballet. GRF has much more literature regarding its use and measurement in sport, particularly in running and general gait analysis.

Ground Reaction Forces

Ground reaction force is the force absorbed by the dancer when landing a foot on the ground, whether from a step or a jump. GRF is equal in magnitude, but opposite in direction of the force that the body exerts on the floor through the foot.[11,28]

GRF is typically measured through the use of a force plate or platform. The force plate has been shown through various studies to have high validity in measuring GRF and center of pressure.[21,33] It is even used as a criterion reference in more recent studies evaluating the effectiveness of other equipment used to measure GRF.[33]

Very few studies examined GRF when landing from jumps, but those who have looked at athletic populations have evaluated gymnasts.[15] While gymnastics usually involves more high power, ballistic movements than ballet, it is similar in the athlete's articulation through the lower limb and aesthetic qualities unseen in most other sports. Division I NCAA gymnasts have been shown to have higher GRF in jump landings when compared to recreational athletes.[15] Gymnasts also usually have minimal hip, knee, and ankle flexion in landings.[15] These actions are typically thought to decrease the amount of energy transferred to the athlete upon landing.

Most ballet jumps utilize these actions (hip, knee, and ankle flexion) as an integral part of landings. This is emphasized through the use of demi plié, which increases hip, knee, and ankle flexion.[15] Studies have demonstrated that subjects landing on the balls of their feet while flexing their ankles and knees when landing from a jump, have lower GRF than those with less flexion or those landing flat-footed.[11,28,34]

Whether or not the use of demi plié and foot articulation affects GRF in dancers has yet to be determined. Other factors have been shown to reduce jump-landing GRF, such as instruction through verbal and auditory cueing.[11] However, these studies have been conducted in general populations of non-athletes, and generally in younger children who may have less ingrained landing patterns.[11,15] Nonetheless, many dancers will focus on decreasing the sound of their pointe shoes striking the floor, especially when landing on harder floor surfaces.[13] This may actually be a method of reducing GRF when introducing ballet technique that is already used. Initially this may have begun with an aesthetic purpose, but now is being shown to be a potentially injury-saving mechanism. The use of imagery, on the other hand, while used widely throughout dance instruction, has not necessarily been shown to be effective in the use of decreasing GRF.[11]

The proper use of jumping technique has been emphasized in the literature in order to decrease undesired biomechanical forces, but most dance instruction focuses on take off mechanics when jumping.[12,13] Proper landing technique includes initial contact of the toes with the floor, contact of the ball of the foot with the floor, progressive lowering of the foot to a flat position, and finally single heel contact.[13] Double heel strike occurs when the heels contact the ground initially after a jump, leave the ground while the balls of the feet remain planted, and then strike the ground a second time when coming to a resting position. Double heel strike has been

noted to be poor technique and a possible cause for increased GRF and therefore potentially increased risk for injury.[12,14]

Although higher incidence of GRF has been linked with higher incidence of injury, no direct evidence currently exists.[11] Three main studies have investigated GRF in ballet jump landings while wearing various dance footwear, but none have directly or indirectly addressed injury.[12,13,20] Chockley[12] explored the differences in GRF when landing a sauté ballet jump both en pointe and on flat in pointe shoes, and found that GRF was greater when landing on flat. These results were likely due to the biomechanics of jumping en pointe that restrict greater jump height and therefore reduce landing GRF. Walter et al.[13] explored the difference in GRF landing from an assemblé both in pointe shoes and in flat technique shoes and found that GRF was greater when landing on flat. These findings agree, but are in contrast to the general hypothesis of the dance community. The most recent study on GRF in ballet jump landings compared split-soled shoes, traditional out-sole shoes, barefoot conditions, and five-toed forefoot shoes. No statistically significant difference was found for maximum GRF, but the number of peaks of force during landing (correlating to double heel strike) was highest for traditional out-soled shoes and lowest for the five-toed forefoot shoes.[20] Whether or not there would be a positive impact of five-toed forefoot shoe usage in ballet on injury reduction is unseen, but more important is understanding the culture and history of ballet and ballet technique. It is highly unlikely that such a shoe would ever make it into a classical ballet studio.

While GRF has not been linked directly to injury at this point in time, further study of GRF in ballet jump landings is indicated in order to determine the effects of different jump conditions, as well as to explore the impacts of various factors within shoe conditions.

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APPENDIX C

SUMMARY SAFEGUARD STATEMENT

INFORMED CONSENT STATEMENT

INDIANA UNIVERSITY INSTITUTIONAL REVIEW BOARD (IRB) REVIEW

SUMMARY SAFEGUARD STATEMENT

IRB STUDY NUMBER: 1205008695

PRINCIPAL INVESTIGATOR: C. Docherty

DOCUMENT DATE: 5/15/12

THIS FORM MUST BE NEATLY TYPED. (DO NOT TYPE ON THE REVERSE SIDE OF ANY FORMS). **Note: To check a box on this form, double-click the box and select "Checked" under "Default Value."**

STUDY TITLE: **Ground Reaction Forces in Ballet: Differences according to Footwear and Jump Conditions**

Please type only in the gray boxes. To mark a box as checked, double-click the box, select "checked", and click "OK".

SECTION I: STUDY DESCRIPTION

A. Please describe (in lay terms) the general objective(s) of the proposed research , including research question(s), hypothesis, and a short summary of the main interactions/interventions. If appropriate, describe any usual methods, that were considered, but not chosen, and why.

Ballet dancers are a group of artists prone to high rates of injury, particularly to the lower extremity. While the literature supports this statement, there has been little research to date on the underlying cause of these injuries. The biomechanics and forces associated with dance movements are important in this understanding. Therefore, the purpose of this study is to investigate the maximal ground reaction force when ballet dancers land from two jump conditions in pointe shoes, in flat ballet slippers, and in barefoot. If it is shown that particular jump conditions or shoe types demonstrate higher ground reaction forces, then further studies can determine if this force increases injury rate. It is anticipated that pointe shoes and the assemble jump condition (smaller jump) will show the least amount of ground reaction forces.

SECTION II: HIPAA

A. Are you part of a covered entity or are you involving a covered entity in your research? Please review the **Covered Entity Checklist** for guidance.

☒ **NO**. You are not subject to HIPAA. For additional information, please see the **Covered Entity Checklist** available on the IU Human Subjects Office website. Proceed to Section III.
☐ **YES**. Continue below:

B. Will protected health information (PHI) be utilized, accessed, collected, or generated as part of the study? For additional guidance on PHI, please refer to the definitions in the Standard Operating Procedures document.

☒ **NO**. Your research is not subject to HIPAA. However, will health information (that is not PHI) be used that is:
- ☒ De-identified?
- ☐ Part of a Limited Data Set?
  - ☐ Health information will be received from a separate covered entity from that of the investigator. You must establish a data use agreement with the entity providing the health information.
  - ☐ Health information will be obtained from within the investigator's own covered entity. No data use agreement is required.
- ☐ No health information will be utilized in any form.

☐ **YES**. Your research is subject to HIPAA. Complete the HIPAA& Recruitment Checklist.

SECTION III: PERFORMANCE SITE

☒ Indiana University
- ☒ IUB Campus. Please state school/department/location(s): HPER/Kinesiology
- ☐ IUPUI Campus. Please state school/department/location(s): _____
- ☐ Bradford Woods
- ☐ Center for Survey Research
- ☐ Center for Evaluation & Education Policy (CEEP)
- ☐ Indiana CTSI Clinical Research Center*
- ☐ Indiana Institute on Disability and Communication
- ☐ IU Simon Cancer Center*
- ☐ Krannert Institute of Cardiology*
- ☐ Kinsey Institute
- ☐ Oral Health Research Institute
- ☐ Other: _____

☐ Health & Hospital Corporation of Marion County
- ☐ Bell Flower Clinic
- ☐ Midtown Mental Health*
- ☐ Wishard Memorial Hospital*
  - ☐ Community Health Clinics/Centers
  - ☐ Hospital/ER
  - ☐ Non-primary care
    - ☐ Wishard Specialty Clinics
    - ☐ OB/GYN Clinics

☐ Indiana University Health (Clarian) Facilities
- ☐ Bloomington Hospital
- ☐ Beltway Centers
- ☐ Methodist Hospital
- ☐ Methodist-Affiliated Centers/Private Practices
- ☐ North Hospital
- ☐ Riley Hospital for Children
- ☐ University Hospital
- ☐ West Hospital
- ☐ Other: _____

☐ IU Health Clinics. Please list location:_____.
☐ IU Medical Group Specialty Clinic (IUMG-SC). Please list location:_____.
☐ Larue Carter Hospital
☐ Monroe County Community School Corporation. Please list school:_____.
☐ Regenstrief Institute
☐ Rehabilitation Hospital of Indiana
☐ Richard L. Roudebush Veterans Affairs Medical Center*. (Complete the Request Form for VA Research)
☐ Other: _____

** Additional information and/or approvals may be required prior to submitting and/or initiating the research. Please see the IU Human Subjects Office website and check with the specific performance site for additional information.*

B. Please list other facilities not under the direct supervision of the investigator where research-related procedures will be performed (e.g. pathology, nursing, pharmacy, radiology, counseling). *

You must ensure these persons/facilities are kept adequately informed about the study and their research-related duties and functions as they relate to the protection of human participants.

SECTION IV: SUBJECT POPULATION

A. **Subject Population**. Check all subject population categories below for which there is a reasonable expectation of enrollment into this research study:

- ☐ **Children** (Complete the Request Form for the Inclusion of Children in Research)
- ☐ **Cognitively Impaired** (Complete the Request Form for the Inclusion of Cognitively Impaired Individuals in Research)
- ☐ **Economically/Educationally Disadvantaged**
- ☐ **Pregnant Women, Human Fetuses, or Fetal Material** (Complete the Request Form for the Inclusion of Pregnant Women, Human Fetuses, and Neonates in Research)
- ☐ **Prisoners** (Complete the Request Form for the Inclusion of Prisoners in Research)
- ☐ **Subjects Outside of U.S. Targeted for Enrollment** (Complete the Transnational Research Information Form)
- ☐ **Veterans** or research funded by the VA, utilizing VA effort, property or resources, or enrolling VA patients. (Complete the Request Form for VA Research)
- ☒ **Students**. When there is a teacher-student relationship dynamic or when using a student subject pool, complete the following questions:

1. Clarify the necessity for involving students in the research: This research is interested in investigating characteristics of elite-level ballet dancers. The ballet major program through the Jacobs School of Music at IU best reflects this population.

2. Explain how the possibility of coercion or undue influence will be minimized when informed consent is being sought: The investigators will not be directly supervising any students who are involved in this project.

3. Explain what genuinely equivalent alternatives are available for students who wish not to participate: Students will not be receiving any compensation. Therefore, the alternative to not participate is just as valid and acceptable as participating.

B. **Inclusion/Exclusion**. List specific eligibility requirements for subjects, including those criteria which would exclude otherwise acceptable subjects (e.g. inclusion/exclusion criteria).

Subjects must be female, full-time students at IUB enrolled as ballet majors and aged 18-25 years old. Subjects may not have a history of acute lower extremity injury within the last six weeks, a history of lower extremity surgery within the last eight weeks, nor be experiencing any symptoms of acute illness at the time of testing.

C. **Number of Subjects**. State the number of subjects to be involved in the research (i.e. number of subjects who will receive research intervention, or about/from whom information or specimens will be collected) both locally and nationally (if a multi-center study).

45

NOTE: The number provided will be the maximum number of subjects approved to participate in this research.

SECTION V: RECRUITMENT

NOTE: Study information will be released to the Clinical and Translational Science Institute (CTSI) for the research study listing. To opt out of this listing requirement you will need to get opt-out approval from Dr. Anantha Shekhar, PhD, MD, Director of Indiana CTSI, prior to IRB submission. For additional information or to request opt-out approval, please contact Patrick McGuire at (317) 278-2176 or pacmcgui@iupui.edu.

A. Is this research subject to HIPAA? (refer to Section II above)

- ☐ **YES**. Do not answer questions 1-3 below. Instead, complete the **HIPAA & Recruitment Checklist**.
- ☒ **NO**. Answer questions 1-3 below.

1. Describe how potential subjects will be initially identified (include specific source, e.g. databases, medical records, advertisements, newsletters, self-referral, physician referral, from clinics, etc.):

Subjects will be identified through the ballet majors program during their daily required technique class.

2. Describe how potential subjects who are identified will be contacted (e.g. letter, phone call, face-to-face) and who will be contacting them (e.g. their physician, research coordinator, nurse, etc.). Include a copy of all information to be shared with or intended to be seen by potential subjects.

Participants will be recruited through announcements during their daily required ballet majors technique class (see attached recruitment script,) or by a flyer posted in the School of Music building (see attached flyers.)

3. Is the investigator currently conducting competing studies? Competing studies refers to two or more studies which utilize overlapping or very similar eligibility criteria.
   ☒ No.
   ☐ Yes. Please describe the plan to ensure fair and unbiased recruitment:

NOTE: Allowing the Principal Investigator or the subject to choose one study over another is rarely acceptable. Consider randomization procedures or exclusive enrollment in one study at a time.

SECTION VI: STUDY PROCEDURES

List all methods by which information or data about or from subjects will be obtained, including any drugs or devices to be used on human subjects and all procedures/interventions that are being performed that would not otherwise be performed outside of the research study [e.g. an investigational drug, a blood draw that is taken purely for research (not treatment purposes) or a standardized survey that is being completed solely for the purposes of this research]. Describe the frequency and duration of the procedures.

All subjects will report to the Athletic Training Research Laboratory for one testing session. Each session will last approximately one hour. At the beginning of each session, the subject will complete a health history questionnaire, which will cover exclusion criteria and demographic information. In addition, they will also complete a questionnaire regarding their ballet history and their dance footwear usage. Each dancer will be allowed up to ten minutes to perform a short ballet warm-up.

After the warm-up, three anatomical markers will be applied to the dancers leg using foam pads. Palpation will be used to find these landmarks. The jumps that will be performed include the classical ballet assemble jump (a jump from one foot to two feet) and the grand jete jump (a split type jump from one foot to the other foot.) The dancers will be allowed to attempt each jump condition until they are comfortable with the procedure.

The runway on which the dancers will jump will be clearly marked in tape with an "X" at the beginning, leading up to the standard recessed force plate which will also have an "X" marked in the center in tape. In order to perform both the practice trials and the test trials, the dancer will be instructed to center their feet on the "X" marked in tape at the beginning of the runway, in a classical fifth position, with their foot of preference in front. They will then be instructed to approach the force plate down the runway in a typical fashion seen during grand allegro. They will be asked to land onto the force plate from the jump condition (assemble or grand jété), and to gauge their necessary location of jump take-off from this requirement.

After the dancer feels comfortable with the runway, jump, and landing procedure and has finished her practice trials, she will perform three trials of each jump in three shoe conditions – barefoot, flat technique shoe, and pointe shoe. The orders of both the jumps and the shoe conditions will be randomized for each dancer. Any trial in which the dancer does not land on the force plate directly from the jump or has any other jump error will be voided and re-attempted until there are a total of three measurable trials for each condition. Video recording will be taken in order to later measure jump height and horizontal jump distance. The dancer will be allowed to rest in-between each trial as long as desired.

NOTE: Please include all surveys, instruments, survey/focus group questions, etc. that will be used for this research.

SECTION VII: RISK/BENEFIT RATIO

A. State the potential risks – for example, physical, psychological, social, legal, loss of confidentiality or other – connected with the proposed procedures.

   There is a minimal risk of participating in this study. A participant may fall during trials or may experience slight muscular soreness the following day.

B. State the potential benefits to be gained by the **SUBJECT**.

   There is likely no benefit to be gained by the individual. However, it is an opportunity for them to actively practice proper jumping technique.

C. State the potential benefits or information which may accrue to **SCIENCE** or **SOCIETY**, in general, as a result of this work.

The potential benefits to dance medicine and science, as well as the dance community at large, including an increased awareness of potential sources of injury to dancers. Conclusions gained from this research may affect how dancers are trained and therefore reduce pain and injury.

D. Explain how the potential risks to subjects are reasonable in relation to anticipated benefits.

The risk to the participants is minimal, particularly in contract to the possible benefit to athletic training education, dance medicine, and dance education and training.

SECTION VIII: PROTECTION PROCEDURES

A. Describe procedures for protecting against, or minimizing, the potential risks described in Section VII, including using procedures that are already being performed on subjects for diagnostic, treatment, or standard purposes, when appropriate.

The dancers will be given appropriate time to warm-up their bodies before attempting the jump trials. They are also given practice trials in order to familiarize themselves with the runway set-up and the force plate landing. The jumps being performed are very typical, frequent jumps for the dancer, and they are therefore very comfortable performing these movements.

B. Explain provisions to protect privacy interests of subjects. This refers to how access to subjects will be controlled (e.g. time, place, etc. of research procedures).

Data will be recorded using a number code to identify subjects. Only one list will exist to link subject's names to their number code, and it will be stored in a secure file that only the research team will have access to. The code list will be destroyed in the year 2013, once the study has been completed and the data have been analyzed. Subjects will not be identified in reports.

C. Is this a multi-center clinical trial?

- ☒ No. Continue to the next section.
- ☐ Yes. Is the PI the lead investigator?
  - ☐ No. Continue to the next section
  - ☐ Yes. Describe the plan for the management and communication of multi-site information that may be relevant to the protection of participants (e.g. unanticipated problems, adverse events, interim analysis, modifications, etc.).

SECTION IX: DATA SAFETY MONITORING PLAN

For all research that is **greater than minimal risk**, a Data Safety Monitoring Plan (DMSP) must be developed. This is a plan to assure the research includes a system for appropriate oversight and monitoring of the conduct of the study to ensure the safety of subjects and the validity and integrity of the data.

- ☒ N/A. The research is minimal risk.
- ☐ The DSMP is contained in the protocol. State where in the protocol the description is located: _____
  NOTE: Ensure that all points outlined below are addressed in the description in the protocol. If any points are not addressed, within the protocol, they should be addressed below.
- ☐ The DSMP is NOT contained in the protocol; however, this is a repository/database protocol and the primary risk is that of loss of confidentiality; thus, I do not need to complete this section.
- ☐ The DSMP is NOT contained in the protocol. Complete the questions below.

A. Who will be responsible for the data and safety monitoring? (Examples include: a DSMC or DSMB, medical monitor, investigator, independent physician) **Clarify if this individual or committee is independent from the sponsor and/or investigator.**

B. What will be monitored. (Examples include: data quality, subject recruitment, accrual, and retention, outcome and adverse event data, assessment of scientific reports or therapeutic development, results of related studies that impact subject safety, procedures designed to protect the privacy of subjects)

C. What are the procedures for analysis and interpretation of data, the actions to be taken upon specific events or endpoints, the procedures for communication from the data monitor to the IRB and site, and other reporting mechanisms?

D. What is the frequency of monitoring? (The appropriate frequency of data and safety monitoring will be dependent on the nature and progress of the research; however, monitoring must be performed on a regular basis (e.g, at least annually).

E. What information will be reported to the IRB? (Minimally, the IRB requires the following information at the time of continuing review: 1) frequency and date(s) of monitoring; 2) summary of cumulative adverse events; 3) assessment of external factors (i.e. scientific reports, therapeutic developments, results of related studies) that impacted the safety of subjects; 4) summary of subject privacy and research data confidentiality outcomes; and 5) any changes to the risk-benefit ratio.

SECTION X: PAYMENT FOR PARTICIPATION

A. Will subjects be paid for participation in the study (e.g. monetary, free services, gifts, course credit, including extra credit)?
☒ No. Proceed to next section.
☐ Yes. Complete items 1-3 below.

1. Explain the payment arrangements (e.g. amount and timing of payment and the proposed method of disbursement), including reimbursement of expenses. **NOTE:** Payments must accrue and not be contingent upon completion of the study. However, a small payment (bonus) for completion of the study may be approved by the IRB if it is found to not be persuasive for the subjects to remain in the study.

2. Justify the proposed payment arrangements described in section B. (e.g., how this proposed payment arrangement is not considered to be coercive).

3. Explain if there will be any partial payment if the subject withdraws prior to completion of the study (e.g. prorated). Note: This payment may be paid at the end of the subject's participation or at the end of the study.

SECTION XI: INFORMED CONSENT PROCESS

☐ **Check here if this study will only enroll children and the parental/guardian permission (consent) process has already been explained on the Request Form for the Inclusion of Children in Research. You do not need to complete section A below.**

☒ **A. I WILL be obtaining informed consent from all subjects.**

1. **When (in what timeframe) and where (what setting) will consent take place?** Indicate any waiting period between informing the subject and obtaining consent. The timeframe and any waiting should ensure the prospective subjects or their legally authorized representatives are provided sufficient opportunity to consider whether or not to participate in the study.

   Immediately prior to participating in the project, informed consent will be obtained. Subjects will be given time to read, comprehend, and ask any questions regarding the information prior to signing the informed consent document.

2. **Who will be responsible for obtaining initial and ongoing consent? (check all that apply)**

   ☐ Principal Investigator
   ☒ Co-Investigator
   ☐ Other (specify):

   NOTE: Individuals who will be obtaining consent must be listed on the Investigator List.

   a. **Explain how these individuals will be adequately trained to conduct the consent interview and answer subject's questions (check all that apply):**

      ☒ Passed the required Collaborative Institutional Training Initiative (CITI) modules
      ☐ Attended the Research Coordinator Education Program (RCEP)
      ☐ Attended the Research Coordinator Certification Program (RCCP)
      ☐ Received study-specific training from study personnel

☐ Other (specify): _____

b. Indicate in what language(s) the consent interview will be conducted.

☒ English
☐ Spanish
☐ Other (specify):

c. If the consent interview will be conducted in a language other than English, state how the interview will be conducted (e.g. use of an interpreter):

NOTE: Ensure that language-appropriate consent documents are submitted with this application.

3. **Explain how subjects' privacy will be protected during the consent process.** This refers to how access to subjects will be controlled (e.g. time, place, etc. of consent procedures).

   Subjects will be given time to read the appropriate documents as well as to ask questions. This will be done in a quiet, controlled environment.

4. **Indicate any factors that might result in the possibility of coercion or undue influence. (check all that apply)**

   ☒ the research will involve students of the investigator(s)
   ☐ the subjects will be recruited through institutions with which the PI has a close relationship
   ☐ Other (please specify):

   Describe steps taken to mitigate the possible coercion: Subjects will not be students that the investigator directly supervises.

☐ **B. I am requesting a <u>waiver of the informed consent process (i.e. no consent document)</u> for (check all that apply):**
   ☐ **the entire study.**
   ☐ **recruitment only (VA requirement: please see the sample language provided in VA Waivers for Recruitment located on the IU Human Subjects Office website).**
   ☐ **a specific minimal risk research activity or procedure that is part of the study: _____.**

For the IRB to grant a waiver of informed consent, the below criteria must be satisfied. Please provide a response to each criterion.

1. The research involves no more than minimal risk to the subject. If you are requesting a waiver of informed consent for part of the study (e.g. recruitment or a specific minimal risk activity or procedure), please state to which activity/procedure the waiver request applies and explain how this criterion is satisfied.

2. Explain how the waiver will not adversely affect the rights and welfare of the subjects.

3. Explain how the research could not be practicably carried out without the waiver.

4. Explain how, if appropriate, subjects will be informed of pertinent results at the conclusion of the study.

5. The research is **NOT** FDA-regulated (i.e. The activity is NOT an experiment or does NOT involve one or more of the following test articles: foods or dietary supplements that bear a nutrient content claim or a health claim, infant formulas, food and color additives, drugs for human use, medical devices for human use, biological products for human use, electronic products. Additionally, **NONE** of the following can be true:, the research involves using the test article with

one or more participants, the research is being done as part of an IND or IDE submission, the data may be submitted to the FDA, or the data may be held for inspection by the FDA).

6. **ONLY COMPLETE FOR RESEARCH AND DEMONSTRATION PROJECTS CONDUCTED BY OR SUBJECT TO THE APPROVAL OF STATE OR LOCAL GOVERNMENT OFFICIALS.** In order for the IRB to approve a waiver of informed consent for a research or demonstration project, conducted by or subject to the approval of state or local government officials, it must NOT be FDA-regulated and be designed such that it studies, evaluates, or otherwise examines one of the following (check all that apply):
   ☐ public benefit or service programs;
   ☐ procedures for obtaining benefits or services under those programs;
   ☐ possible changes in or alternatives to those programs or procedures; or
   ☐ possible changes in methods or levels of payment for benefits or services under those programs.

☐ **C. I am requesting a <u>waiver of *written documentation* of informed consent</u> (i.e. a consent process will occur, but no signature will be obtained from the subject).**

☐ Written statement regarding the research has been attached. Statement will be provided to subjects upon their request. Please explain:

.

For the IRB to grant a waiver of written documentation of informed consent, EITHER of the following criteria must be met. Please indicate which criterion is met and provide an appropriate response below.

☐ 1. The only record linking the subject and the research would be the consent document and the principal risk would be potential harm resulting from a breach of confidentiality, and the research is not FDA-regulated. Each subject will be asked whether the subject wants documentation linking the subject with the research and the subject's wishes will govern. Please explain:

OR

☐ 2. The research presents no more than minimal risk of harm to subjects and involves no procedures for which written consent is normally required outside of the research context. Please explain:

☐ **D. I am requesting modification to the required elements for informed consent document for:**
☐ **the entire study**
☐ **a specific minimal risk research activity or procedure that is part of the study**

Check all of the required elements below that you are requesting to modify or omit from the informed consent document:

☐ Statement that the study involves research
☐ Explanation of the purposes of the research
☐ Expected duration of subject participation
☐ Description of procedures to be followed
☐ Identification of any procedures that are experimental
☐ Description of any reasonably foreseeable risks or discomforts to subjects
☐ Description of benefits (to subjects or others) that may reasonably be expected from the research
☐ Disclosure of appropriate alternative procedures or courses of treatment
☐ Statement describing the extent to which confidentiality of records identifying subjects will be maintained
☐ Explanation regarding any compensation
☐ Explanation of available medical treatments if injury occurs
☐ Contact information for questions about the research, research-related injury, or subject rights
☐ Statement that participation is voluntary

For the IRB to grant a modification to the required elements of informed consent, the below criteria must be satisfied. Please provide a response to each criterion.

1. The research involves no more than minimal risk to the subject. If you are requesting a waiver of informed consent for part of the study (e.g. a specific minimal risk activity or procedure), please state to which activity/procedure the waiver request applies and explain how this criterion is satisfied

2. Explain how the modification will not adversely affect the rights and welfare of the subjects.

3. Explain how the research could not be practically carried out without modification of informed consent.

4. Explain how, if appropriate, subjects will be informed of pertinent results at the conclusion of the study.

5. The research is **NOT** FDA-regulated (i.e. The activity is NOT an experiment or does NOT involve one or more of the following test articles: foods or dietary supplements that bear a nutrient content claim or a health claim, infant formulas, food and color additives, drugs for human use, medical devices for human use, biological products for human use, electronic products. Additionally, **NONE** of the following can be true: the research involves using the test article with one or more participants, the research is being done as part of an IND or IDE submission, the data may be submitted to the FDA, or the data may be held for inspection by the FDA).

SECTION XII: ADDITIONAL REVIEWS

☒ N/A. This research does not require any additional institutional reviews. Proceed to next section.

A. Will this study specifically enroll cancer patients (e.g. is the study focused on cancer treatment or care or does the study include a control group of cancer patients) or involve cancer-related gene therapy?
☐ No.
☐ Yes. You must first obtain approval from the Scientific Review Committee (SRC) prior to submitting to the IRB. Please include that approval with your IRB study submission. Please contact the SRC at (317) 274-0930 or crosrc@iupui.edu for additional information.
☐ Check here if this study is a retrospective chart review involving cancer patients; SRC approval is NOT necessary.

B. Does the study involve recombinant DNA (e.g. gene therapy)?
☐ No.
☐ Yes. IBC or BHC protocol number:

C. Does the study involve radiation / radioactivity (e.g. x-rays, nuclear medical scans) in addition to what is used for standard clinical treatment?
☐ No
☐ Yes. Radiation Safety approval must be obtained if radiation beyond standard of care is involved. Concurrent IRB and radiation safety review is permissible; however, final IRB approval will not granted until documentation of radiation safety approval is provided.

D. Does this study involve the use of *non-cancer-related* gene therapy?
☐ No.

☐ Yes. Has the proposal been submitted to the Indiana CTSI Clinical Research Center (CRC) Advisory Committee? (**NOTE**: It is a requirement of the School of Medicine for all non-cancer related gene therapy studies to be reviewed by the CRC Advisory Committee. Additionally, it is the CRC's requirement that approval be granted from them prior to IRB submission.)

- ☐ No. You must submit to the CRC Advisory Committee *before* you can submit to the IRB. Please call (317) 278-3446 for more information.
- ☐ Yes. Include a copy of that approval with this study submission.

SECTION XIII: FEDERAL FUNDING

A. Is this research funded by a federal agency (e.g. DHHS, NIH, VA, CDC, ICTSI, etc.), or has it been submitted to a federal agency for funding?

☒ No. Proceed to the next section.

☐ Yes. Please ensure copies of the entire funding proposal and DHHS-approved sample informed consent (if applicable) are available to the IRB.

NOTE: If this is a federally-funded study, you will be required to track the race and ethnicity of subjects enrolled. This is reported to the IRB at the time of continuing review.

SECTION XIV: INVESTIGATIONAL TEST ARTICLES

☒ N/A. No investigational drugs or devices are being studied in this research.

☐ This study involves a device that is exempt from the IDE requirements. Please submit the IDE Checklist or notification from the FDA confirming status of this device.

If you are studying an investigational drug or device, an IND or IDE may be required. Please see the IND Checklist or IDE Checklist for more information.

INVESTIGATIONAL DRUGS

A. Name of Drug Sponsor:

_____

____

Name of Drug: _____

Study Phase: ☐ I ☐ I/II ☐ II ☐ II/III ☐ III ☐ III/IV ☐ IV

☐ An IND is not required. Please submit the IND Checklist or notification from the FDA confirming exempt status.

☐ An IND is required and has been obtained for this drug. IND Number:

_____

1. Provide verification of the IND number (choose all that apply):
   - ☐ Documentation from the FDA provided
   - ☐ IND number included in the sponsor protocol, list the page number where the IND number is located

2. Does the investigator hold the IND?
   - ☐ No
   - ☐ Yes. Before approval can be granted, the investigator must meet with the Office of Research Administration staff to discuss the additional responsibilities as a sponsor of an IND. Please contact the IU Human Subjects Office at (317) 274-8289 and submit documentation from them verifying this discussion has taken place.

3. Will services of the Investigational Drug Services (IDS) be used?

☐ Yes
☐ No. The investigator must demonstrate understanding of the handling and control of investigational test articles by reviewing the SOP for Investigational Test Articles. Check here ☐ to confirm the investigator has read the SOP and agrees to comply with the policies and procedures outlined.

INVESTIGATIONAL DEVICES

B. Name of Device Manufacturer:_____ Name of Device:
_____

The IRB is required to determine whether or not the device is significant risk. To help in this determination, please provide the sponsor's documentation on the risk assessment and the rationale used in making the risk determination. ***Please provide the investigator's assessment of the device risk below***:

☐ Nonsignificant Risk (NSR) Device. Please provide a risk assessment and rationale for this risk determination:

☐ Significant Risk (SR) Device

☐ An IDE has been obtained for this device. IDE Number:
_____

1. Provide verification of the IDE number (choose all that apply):
   ☐ Documentation from the FDA provided
   ☐ IDE number included in the sponsor protocol, list the page number where the IDE number is located

2. Does the IU affiliated investigator hold the IDE?
   ☐ No
   ☐ Yes. Before approval can be granted, the investigator must meet with the Office of Research Administration staff to discuss the additional responsibilities as a sponsor of an IDE. Please contact the IU Human Subjects Office at (317) 274-8289 and submit documentation from them verifying this discussion has taken place.

3. The investigator must demonstrate understanding of the handling and control of investigational test articles by reviewing the SOP for Investigational Test Articles. Check here ☐ to confirm the investigator has read the SOP and agrees to comply with the policies and procedures outlined.

INDIANA UNIVERSITY INFORMED CONSENT STATEMENT FOR

Ground Reaction Forces in Ballet: Differences according to Footwear and Jump Conditions)

You are invited to participate in a research study of the ground reaction forces that occur during ballet jumps. You were selected as a possible subject because you are a ballet major at Indiana University, Bloomington. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

The study is being conducted by Dr. Carrie Docherty and Alyssa McPherson in the Department of Kinesiology at Indiana University.

STUDY PURPOSE
The purpose of this study is to determine the forces that are transmitted to a dancer's body when they land from a jump. In particular, it will show if there are differences in these forces when a dancer wears different shoe types or performs different types of jump.

NUMBER OF PEOPLE TAKING PART IN THE STUDY:
If you agree to participate, you will be one of 45 subjects who will be participating in this research.

PROCEDURES FOR THE STUDY:
If you agree to be in the study, you will do the following things:

The study requires you to perform an assemble jump a total of 9 times and a grand jete jump a total of 9 times. First, you will answer a questionnaire regarding your footwear usage in ballet as well as a health history questionnaire. Three adhesive markers will be applied to various spots on your leg, and then you will perform each jump 3 times in flat technique shoes, 3 times in pointe shoes, and 3 times barefoot. You will start approximately 2 meters away from a recessed force plate, run towards the force plate, perform the jump, land in the center of the force plate, and then step off the platform. The force platform is a square metal platform that records the force that you are landing with. You should perform the jump to your maximal effort. You will be allowed to practice the jumps until you are comfortable with the procedure. You will be asked to repeat the trial if it is deemed unacceptable. An unacceptable trial includes; losing your balance, landing with a double heel strike, or not landing in a proper position. Video recordings will be taken during these trials in order to measure jump height and jump distance via computer analysis.

RISKS OF TAKING PART IN THE STUDY:
There is always the risk of muscle soreness from participating in any physical activity. There is also the risk of bone, ligament, tendon, or muscle injury if the jumping procedure is not executed properly.

BENEFITS OF TAKING PART IN THE STUDY:
The benefits to participation that are reasonable to expect are none to the individual. Participating will add to the overall body of knowledge concerning dance science and injury, however.

ALTERNATIVES TO TAKING PART IN THE STUDY:
Instead of being in the study, you have the option to not participate.

CONFIDENTIALITY
Efforts will be made to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Your identity will be held in confidence in reports in which the study may be published. Your information will be assigned a code number. The list connecting your name to this code will be kept in a locked file. When the study is

completed and the data have been analyzed, this list will be destroyed. Your name will not be used in any report. Video data will also be linked to you by your code number. Video data will also be destroyed after the study has been completed and the data analyzed.

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the study investigator and his/her research associates, the Indiana University Institutional Review Board or its designees, and (as allowed by law) state or federal agencies, specifically the Office for Human Research Protections (OHRP) etc., who may need to access your research records.

PAYMENT
You will not receive payment for taking part in this study.

COMPENSATION FOR INJURY
In the event of physical injury resulting from your participation in this research, necessary medical treatment will be provided to you and billed as part of your medical expenses. Costs not covered by your health care insurer will be your responsibility. Also, it is your responsibility to determine the extent of your health care coverage. There is no program in place for other monetary compensation for such injuries. However, you are not giving up any legal rights or benefits to which you are otherwise entitled. If you are participating in research which is not conducted at a medical facility, you will be responsible for seeking medical care and for the expenses associated with any care received.

CONTACTS FOR QUESTIONS OR PROBLEMS
For questions about the study or a research-related injury, contact the researcher Dr. Carrie Docherty at 812/856-6035. If you cannot reach the researcher during regular business hours (i.e. 8:00AM-5:00PM), please call the IU Human Subjects Office at (317) 278-3458 [for Indianapolis] or (812) 856-4242 [for Bloomington] or (800) 696-2949. After business hours, please call the appropriate medical facilities for care.

For questions about your rights as a research participant or to discuss problems, complaints or concerns about a research study, or to obtain information, or offer input, contact the IU Human Subjects Office at (317) 278-3458 or [for Indianapolis] or (812) 856-4242 [for Bloomington] or (800) 696-2949.

VOLUNTARY NATURE OF STUDY
Taking part in this study is voluntary. You may choose not to take part or may leave the study at any time. Leaving the study will not result in any penalty or loss of benefits to which you are entitled. Your decision whether or not to participate in this study will not affect your current or future relations with the Athletic Training Program at Indiana University

SUBJECT'S CONSENT
In consideration of all of the above, I give my consent to participate in this research study.

I will be given a copy of this informed consent document to keep for my records. I agree to take part in this study.

Subject's Printed Name:_____

Subject's Signature:_____**Date**:_____
(must be dated by the subject)

Signature of Person Obtaining Consent:_____**Date**:
_____

APPENDIX D

DATA PROCEDURES FORM

Procedure List

Before subject arrives:

1. Turn on force plate receiver box
2. Set-up video camera
    a. Place camera parallel to runway
    b. Level camera and adjust positioning
3. Place Bioanalysis key/dongle into USB port of computer
4. Open the AMTI Calibration panel
    a. Click Details
    b. Change gain to "500" for all items
    c. Click okay
    d. Exit calibration panel
5. Open the AMTI Netforce software
    a. Click protocol
        i. Click select/view protocol
        ii. Click open file
        iii. Select jump.pro
        iv. Click open
        v. Click ok
    b. Click startup
        i. Select hardware zero
        ii. Finish zeroing the platform
        iii. Click ok

Upon subject arrival:

1. Make sure they understand IRB informed consent form
2. Have them fill out medical history questionnaire
3. Have them complete pointe shoe questionnaire
4. Record subject's age and height
5. Have subject adjust tights and give instructions not to move tights during procedures
6. Give subject testing procedure instructions
    a. Subject lines up on the floor at appropriate starting point
    b. Subject does practice trials of the jump until they feel comfortable with where they need to land on the force plate
    c. Inform subject that when told they will stand on the platform (to have their weight recorded), they will then step off and proceed immediately to starting point to perform their first trial
    d. Subject will then line up on floor at starting point and proceeds with 3 jumping trials in each shoe, then perform the second jump for three trials in each shoe
7. Press record button on camera
8. Open AMTI Software
    a. Click subject
        i. Add subject
        ii. Use subject number as first name
        iii. Click start
        iv. Click tare
        v. Step onto the force plate to record weight
        vi. Click weight
        vii. Weight recorded and accepted, click ok
        viii. Click arm

ix. Press spacebar – this is the subjects first trial
x. Once timer expires, click save and save as same unique file name
xi. Click next

b. To continue with testing
i. Click arm
ii. Press spacebar
iii. After subject jumps, press save and save to unique file name
iv. Click arm for next trial to be started and repeat previous steps (e.g. space bar and save)

9. Close AMTI to open Bioanalysis
10. Click on the start button
11. Click on Bioanalysis
    a. Click analysis
        i. Select gait
        ii. Highlight files you want to analyze and move files
        iii. Click ok
        iv. Select view
            1. Click statistical results
                a. Make sure units are set to metric
                b. Look at Fz Max
12. At the end of each data collection back-up data:
    a. Record Fz Max onto data collection form
    b. Download video data onto computer
    c. Download raw GRF data onto computer

<u>Video Data Processing</u>

1. Turn on Dell laptop
2. Attach device containing video files (flash drive or hard drive)
3. Open Dartfish
    a. Click open new project
    b. Click create
    c. Import saved video for analysis
4. To analyze horizontal distances
    a. Set reference distance using taped 1m distance on the lab floor next to runway
    b. Set marker on subject at central line on tights
    c. Place marker at beginning of jump (defined as maximal knee flexion of take-off leg)
    d. Place marker at end of jump (defined as maximal knee flexion)
    e. Use distance tool to measure and record this horizontal distance
5. To analyze vertical height
    a. Set reference distance using taped 1m distance on the lab floor next to runway
    b. Set marker on subject at central line on tights
    c. Place marker at beginning of jump (defined as maximal knee flexion of take-off leg)
    d. Place marker at highest point of jump by using frame-by-frame analysis
    e. Use distance tool to measure and record this vertical height distance

APPENDIX E

DATA COLLECTION FORM

MEDICAL HISTORY QUESTIONNAIRE

POINTE SHOE QUESTIONNAIRE

Subject # _____ Study # 1205008695

Ground Reaction Forces in Ballet: Differences according to Footwear and Jump Conditions

Data Collection Form

Demographics:

____ No acute LE injury in past 6 weeks
____ No LE surgery in past 8 weeks
____ No acute illness
____ IRB Signed
____ Health history questionnaire received
____ Shoe questionnaire received

_____ Height (in) = _____ cm
_____ Weight barefoot (kg from scale)
_____ Weight-flat (N from force plate)
_____ Weight-pointe (N)
_____ Age

Limb dominance: Right Left
Front leg during jump: Right Left

Practice trials used: _____
Practice trials performed in: barefoot flat technique shoes pointe shoes

Jump Condition #1: Assemblé Grand Jeté
Shoe Condition #1: Barefoot Flat Pointe

Jump/Computer Trial #	GRF	Notes
Trial 1:		
Trial 2:		
Trial 3:		
Re-do		
Re-do		

Jump Condition #2: Assemblé Grand Jeté
Shoe Condition #2: Barefoot Flat Pointe

Jump/Computer Trial #	GRF	Notes
Trial 1:		
Trial 2:		
Trial 3:		
Re-do		
Re-do		

Jump Condition #3: Assemblé Grand Jeté
Shoe Condition #3: Barefoot Flat Pointe

Jump/Computer Trial #	GRF	Notes
Trial 1:		
Trial 2:		
Trial 3:		
Re-do		
Re-do		

Jump Condition #4: Assemblé Grand Jeté
Shoe Condition #4: Barefoot Flat Pointe

Jump/Computer Trial #	GRF	Notes
Trial 1:		
Trial 2:		
Trial 3:		
Re-do		
Re-do		

Jump Condition #5: Assemblé Grand Jeté
Shoe Condition #5: Barefoot Flat Pointe

Jump/Computer Trial #	GRF	Notes
Trial 1:		
Trial 2:		
Trial 3:		
Re-do		
Re-do		

Jump Condition #6: Assemblé Grand Jeté
Shoe Condition #6: Barefoot Flat Pointe

Jump/Computer Trial #	GRF	Notes
Trial 1:		
Trial 2:		
Trial 3:		
Re-do		
Re-do		

Subject # _____ Study # 1205008695

Ground Reaction Forces in Ballet: Differences according to Footwear and Jump Conditions

Medical Questionnaire

1) List any current medical conditions:

_____
_____
_____

2) Have you ever had any surgeries? Yes No
If answered yes, please list:

_____
_____
_____

3) Have you ever had any fractures/broken bones (including stress fractures)? Yes No
If you answered yes, please what type of fracture and when:

_____
_____
_____

4) Do you have any orthopedic problems currently? Yes No
If you answered yes, please list (include date that it began and type of issue):

_____
_____
_____
_____

5) Are you currently suffering from any illnesses (cold, sinus infection, ear infection, etc.)? Yes No

6) Year in the ballet major program: Freshman Sophomore Junior Senior

7) How many hours of dance have you done today? _____

8) How many hours of dance have you done this week? _____

9) Do you perform any type of cross-training (i.e. physical activity other than ballet)? Yes No
If answered yes, please describe your typical physical activities outside of ballet:

_____
_____
_____

Subject # _____ Study # 1205008695

Ground Reaction Forces in Ballet: Differences according to Footwear and Jump Conditions

Pointe Shoe Questionnaire

1) What brand of pointe shoes are you wearing today? (e.g. Freed, Bloch, etc.)

_____

2) What type of pointe shoes are you wearing today? (e.g. Studio II, Sonata, etc.)

_____

3) What size of pointe shoes are you wearing today? _____

4) Age of this pair of pointe shoes: _____

5) What type of flat technique shoe are you wearing today?

_____

6) Age of this pair of flat technique shoes: _____

7) Is the shank a full shank, or ¾ shank? Full 3/4
Is the shank broken? Yes No

8) Do you request a specific maker currently? Yes No
If yes, what maker(s) do you request?

_____

_____

9) Have you requested a specific maker in the past? Yes No

10) How much do you pay on average per pair for your current shoes?

_____

11) Does cost influence your choice of pointe shoes? Yes No

12) Do you typically perform any type of breaking-in treatments to your shoes? Yes No
Did you apply this breaking-in treatment to the shoes that you're wearing today? Yes No
Please describe this breaking-in treatment:

_____

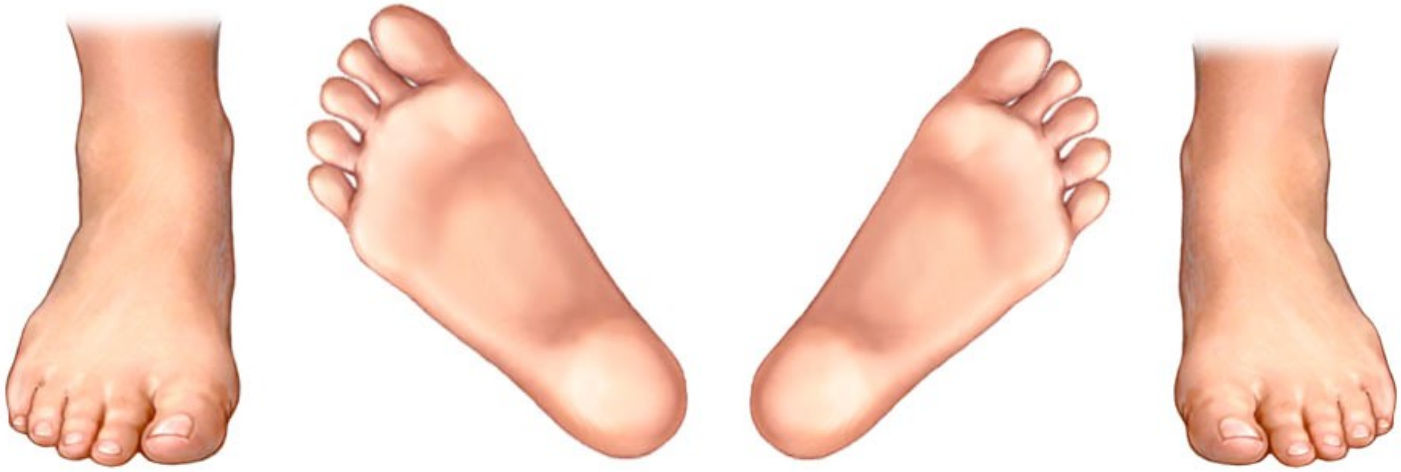
_____

_____

_____

13) Do you use any type of padding, tape, or treatments each time you wear your pointe shoes? Yes No
Are you wearing this type of padding/etc. today? Yes No
Please describe in as much detail as possible: (for instance, if using toe pads, give type or brand if possible)
Also please use the diagram as needed to describe:

_____
_____
_____
_____
_____



Right foot Right foot Left foot Left foot

14) How long have you worn your current *type* of pointe shoes?

_____
_____

15) Before changing to your current type(s) of pointe shoes, what were the previous *two* types of pointe shoes that you used?

_____
_____
_____

16) Please choose your top 3 considerations in picking a type of pointe shoe:
Comfort Box/Platform Shape Vamp Shape Price Durability Fit Shank Style

17) Have you ever had a teacher not allow you to wear a particular brand or type of shoe? If so, what was their rationale (i.e. why did they tell you not to wear this particular type)?

_____
_____
_____

18) How long does a pair of pointe shoes typically last you for class and rehearsal? _____

19) How long does a pair of pointe shoes typically last you for performance? _____

20) How many pairs of pointe shoes would you estimate that you use in a year? _____

21) How long does a pair of *flat* shoes typically last you? _____

22) How many years of classical ballet training do you have? _____

23) Have you ever had any orthopedic injury occur that was associated with changing type of pointe shoes?
Yes No
If yes, please describe:

_____

_____

_____

24) If you were asked to perform a grand jeté, which would be your preferred front leg?
Right Left

25) What have been your roles in the last 3 major performances you've had at IU (or as many as applicable at IU)?
Last performance: Corps Soloist Principal/Pas
Second-to-last performance: Corps Soloist Principal/Pas
Third-to-last performance: Corps Soloist Principal/Pas

APPENDIX F

POWER ANALYSIS

Power Analysis (GRF)

Walter et al. (2011)
Mean 1 = 1742.9
Mean 2 = 1612.7
Std Dev = 257.05
Effect Size = 0.50651

Chockley (2008)
Mean 1 = 735.93
Mean 2 = 531.14
Std Dev = 89.035
Effect Size = 2.3001

Average Effect Size = 1.4033

We will estimate an effect size of 0.8 and power of 0.8 to calculate the require number of subjects for this study as 10.