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The Physics of Cheerleading: Force Production of Cheerleading Stunts

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Abstract

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This study aims to determine the ground reaction forces that are encountered by bases and flyers of a co-ed stunt group when performing a basic toss, a toss hands, and a toss extension. The ground reaction forces of other activities, such as those encountered in figure skating and gymnastics, have previously been studied, but the forces produced by cheerleaders have never before been tested. Data was collected by having cheerleading stunt groups (four males and three females) perform trials of each stunt on force plates. The data showed that both the base and flyer were exposed to large ground reaction forces upon take-off and landing of all of these stunts. The vertical ground reaction forces on the take-off of the bases increased in magnitude as the height of the stunt increased, but none of the others varied statistically significantly based on the type of stunt. On average, the presence of a cushioned cheerleading mat did not significantly affect the ground reaction forces. This was determined through the analysis of the cheerleading stunts and through the conduction and analysis of two other tests. The first test involved measuring the ground reaction forces of EKU women's soccer players when performing standing vertical jumps. The second test was conducted by measuring the landing forces when a medicine ball and shot put were dropped from various heights onto three different surfaces. These studies will hopefully inspire other researchers to continue studying the ground reaction forces of cheerleaders and other aspects of cheerleading, in general.

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Acknowledgements

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Introduction

The number of cheerleaders in the United States reached an all-time high in 2016, with 4.03 million people claiming to participate in the sport ("Cheerleading: Number of Participants," 2018). According to a survey that investigated the participation of high school students in athletics during the 2014-2015 academic year, cheerleading had 128,450 participants, which ranked fourteenth out of the sixty-one sports that were included in the survey. Amongst the female respondents, participation in competitive cheerleading ranked ninth out of all of the sports (The National Federation of State High School Associations, 2015). At the collegiate level, cheerleading is not considered to be an NCAA sport, but debate has occurred over the past few years as to whether cheerleading will be added due to the increasing participation in and increasing difficulty of the sport. Cheerleading made a major stride in December of 2016, when the International Olympic Committee decided to officially recognize cheerleading as a sport. It also gave provisional recognition to the International Cheer Union, which is one of the main steps towards cheerleading becoming an Olympic event (Dennie, 2016). Despite the popularity and recent recognition of the sport, the amount of research that has been conducted involving topics related to cheerleading is minimal. The avenues for research within the sport of cheerleading are vast due to this lack of previously conducted studies, but because one of the major aspects of cheerleading is stunting, especially at the collegiate and competitive levels, this particular study will focus on topics related to stunting.

Background Information

Stunts are one of the most common skills performed by cheerleaders. According to data collected between June of 2006 to June of 2007 at the Research Institute at Nationwide Children's Hospital in Columbus, Ohio, around sixty percent of cheerleading injuries result from performing stunts (Shields, Fernandez, & Smith, 2009, p. 592). When analyzing the data from this same study, it was found that collegiate cheerleading teams had almost three times the number of stunt related injuries per one thousand reported than any other type of cheerleading team (2009, p. 592). The most common injuries encountered by the cheerleaders in this study were ankle injuries, but the prevalence of knee and neck injuries were not far behind (2009, p. 590). As can be seen, injuries are not uncommon in the sport of cheerleading, but research looking into the possible reasons for these injuries has yet to be explored. The problem that is in question in this study is whether the significant impact of ground reaction forces (GRFs) that are encountered by the base and flyer during both take-off and landing of cheerleading stunts increase as the height and difficulty of the stunt increase and whether these ground reaction forces contribute to stunt-related injuries within the sport of cheerleading. Therefore, this study will concentrate on determining and analyzing the vertical ground reaction forces (GRFs) that cheerleaders produce when performing different stunts. This will allow future research to be performed to draw connections between force production, cheerleading stunts, and potential injuries within the sport of cheerleading.

Previous Studies

While the forces produced by cheerleaders has not previously been investigated, there has been research conducted looking into the number and types of cheer related injuries, the force production of landing in similar sports and activities, and the relationship between the cheerleading surface and injuries. These previous studies will be used to understand the importance of conducting this study, as well as give guidelines for how aspects of this study should be conducted.

Cheerleaders and figure skaters perform similar jumping motions when participating in their respective sports. Therefore it is reasonable to investigate studies relating to figure skating to help draw conclusions about the sport of cheerleading. One main commonality between the jumps being performed in both sports is that both are restricted on their landings. Figure skaters cannot fully bend their knees to absorb their body weight when landing their jumps due to their restricting leather skates (Longman, 2001). When performing cheerleading stunts, the flyers cannot fully absorb the shock of their landing because the base that is catching them from behind limits their range of motion. Therefore, the impact from landing jumps for figure skaters results in large amounts of strain being placed on the tibia, knee, femur, hip, and lower back (Longman, 2001).

Due to the significant ground reaction forces of figure skaters jumps mainly being applied to these lower body areas, the majority of figure skating injuries are foot and ankle injuries (Saunders, Hanson, Koutakis, Chaudhari, & Devor, 2014, p.1048). Similarly, it was found that the most common injuries encountered by cheerleaders were ankle injuries. Injuries to the knee and neck were also very prevalent in cheerleaders (Shields, Fernandez, & Smith, 2009, p. 590). The ground reaction forces of cheerleaders should therefore be investigated to understand if these forces are impacting the same body parts as the figure skaters, and potentially as a result, leading to the same lower body injuries.

The height at which landings are performed affects the amount of ground reaction forces that are applied to an individual's body. It has been determined that the average height of the jumps that are performed by figure skaters are approximately 1.33 feet (16 inches, 0.41 meters) for females and 1.67 feet (20 inches, 0.51 meters) for males (Intagliata, & Mayer, 2018). The heights of the cheerleading stunts being performed in this particular study, which are three very basic stunts, are performed at heights of about three feet for the basic toss, approximately five feet for the toss to hands, and between six and seven feet, depending on the height of the base, for the toss to extension. Therefore, when comparing the heights from which landings occur for these two sports, cheerleaders are often falling from much greater heights than figure skaters, which would suggest that these significant ground reaction forces upon encountering the ground after jumping are likely affecting cheerleaders just as much as figure skaters.

In a similar context, participants of gymnastics are also greatly affected by large ground reaction forces that are encountered when performing many of their skills. Slater, Campbell, Smith, and Straker (2015) argue that high impact forces that result from gymnastics landings contribute to the high rate of injuries in the sport (p. 45). In comparison with cheerleaders and figure skaters, gymnasts are also restricted on their landings because a great amount of flexion of the lower body upon landing results in deductions from the individual's overall score (2015, p. 45). It has been found that the most prevalent injuries in gymnasts occur to the ankles, but other lower body injuries are also common. This coincides with the ankles and lower bodies being the most commonly injured body parts of cheerleaders and figure skaters.

In order to determine if the restricted flexion of the lower body affected the ground reaction forces encountered when gymnasts performed certain skills, twenty-one elite women's gymnast performed drop landings, front somersaults, and back somersaults on a force plate. The ground reaction forces of each woman was measured using the force plate and the angles of the ankle, knee, and hip were determined using three-dimensional motion analysis. For the gymnasts, it was found that the vertical ground reaction forces, on average, were between five and thirteen times the body weight of the individual. The hip range of motion had significant associations with the peak ground reaction forces across all three of the gymnastics tricks that were performed in the study (Slater, Campbell, Smith, & Straker, 2015, p. 50). The final conclusion indicated that the rules of gymnastics should be changed to allow increased flexion upon landing gymnastics skills in order to reduce the number of injuries within the sport. For gymnasts, the restriction of the hip angle when landing was found to significantly increase their ground reaction forces, and similarly, this restriction in hip angle is also the issue with flyers when landing their cheerleading stunts. The similarities between gymnastics and cheerleading landings prove its necessary to study the ground reaction forces of cheerleaders to gain a better understanding of how these forces are potentially larger due to the restricted landings, as well as how these forces are impacting cheerleading injuries.

Ground reaction forces are encountered when performing many different activities, but the surface on which the activities occur has been found to cause a variation in the forces that are experienced. Cheerleaders, especially at the collegiate level, are expected to perform on many different surfaces. For example, cheerleaders perform on cushioned mats at competitions, on synthetic turf at football games, and on wood floors at basketball games. It is important to determine whether the type of flooring has an impact on the ground reaction forces that are encountered in order to determine if the flooring is safe for cheerleaders to perform stunts without encountering too significant of ground reaction forces.

The effects of sports flooring on vertical instantaneous loading rates (VILR) and peak vertical ground reaction forces (PVGRF) were investigated by having 41 healthy, active men perform ankle jumps and multi-jumps on two force plates (Malisoux, Gette, Urhausen, Bomfim, & Theisen, 2017, p. 2). The jumps were performed on four different rubber and foam surfaces that varied between 7.5 and 18 millimeters, with the uncovered force plates being the control. The results indicated that the VILR and PVGRF were lowest for the softest flooring and highest for the control, which was the uncovered force plates. The results indicate the type of flooring does provide a difference in the ground reaction forces of jumps and is an important factor when analyzing these forces.

The ground reaction forces for different cheerleading surfaces has not previously been analyzed, but the critical heights of cheerleading surfaces has been investigated, which can give insight into the differing safety of performing stunts based on the surface. The critical heights, which is defined to be the height at which an object can safely fall without obtaining a brain injury, of artificial turf, asphalt, carpet, concrete, dirt, grass, a landing mat, a rubberized track, spring flooring, foam flooring, tile flooring, and a wood gym floor were tested by measuring the impact of three successive drop tests (Shields, B. J., & Smith, G. A., 2009, p. 597). The critical height of the wood gym floor was 4.5 feet (1.37 meters), which was similar to the critical heights of dirt, grass, and asphalt. The cheerleading landing mat in their study had a thickness of 4.0 inches (0.10 meters) and a critical height of 6.5 feet (1.8 meters) when it was placed on top of tile flooring. The critical height of the spring floor, which was 6.38 inches (0.16 meters) in thickness, was 11 feet (3.4 meters). In comparison, in this study, the subjects were landing stunts from heights between about three and seven feet (about 0.9 to 2 meters), but often times, stunts are landed from even greater heights. Therefore, the only stunt that would be considered safe to perform on the gym floor at basketball games or the grass at football games that was performed in this study is the basic toss.

Therefore, Shields and Smith (2009) concluded that the wood gym floor, dirt, grass, and asphalt were non-impact-absorbing surfaces, and, ultimately, should not be cheered on. The only surfaces that were determined to have large enough critical heights to perform 2-level stunts and tosses were the 6.38-inch thick spring floor, which included layers of spring and foam, and the 4-inch thick landing mat. The data from this study was strictly based on preventing brain injuries, so the critical heights cannot directly be applied to other cheerleading injuries, but it can give a good indication of whether the surfaces should be considered safe for performing stunts. This idea of the critical heights of different gymnastics surfaces can be investigated using ground reaction forces to determine if the forces differ in a similar pattern to the critical heights, which could then indicate a relationship between the vertical ground reaction forces and the critical heights of cheer surfaces.

Methodology

Recruitment

The cheerleaders that were recruited to participate in the study were healthy members of the Eastern Kentucky University cheerleading team. For this particular study, one male cheerleader and one female cheerleader were required to come in at the same time in order to perform co-ed cheerleading stunts. The cheerleaders were recruited by word of mouth and through email correspondence. Participation in the study was voluntary and there were no rewards given to those that participated in the study.

Healthy members of the Eastern Kentucky University women's soccer team were also recruited by word of mouth to participate in the study. Their participation was necessary for conducting the vertical jump testing. All of these individuals voluntarily participated in the study.

Procedure

The cheerleaders were asked to come into the exercise and sport science lab in the Moberly building on Eastern Kentucky University's campus. Each cheerleader had their height and weight measured and recorded. The result from this was recorded in order to be further analyzed amongst the ground reaction force data collected later in the study. The participants then completed a health history questionnaire to ensure that their participation in the study was reasonable.

After all of the background information had been collected, the cheerleaders warmed up until they felt they were adequately ready to perform stunts. The female member of the stunt group proceeded to stand on one force plate while the male member of the stunt group stood on the other force plate (Image 1). This allowed for the ground reaction forces of each individual to be determined and analyzed separately. The cheerleaders were then asked to perform trials of three basic stunts: the basic toss, toss to hands, and toss to extension.

The resultant ground reaction forces for each of the members of the stunts group were recorded for every trial. After all of this data was collected, the participants were free to leave the lab and their participation in the study was completed.

In order to further analyze the effect of the surface on the resultant ground reaction forces, a medicine ball and a shot put were dropped from heights of 1.02 meters and 2.95 meters onto the force plates. At least six trials were performed from each height with each different ball. The trials were repeated with the old cheerleading mat (3.81 cm thick) placed on top of the force plates and with the good cheerleading mat (4.45 cm thick) placed on top of the force plates. The peak landing forces of these objects were recorded.

For the final portion of this study, EKU women's soccer players were asked to come into the lab. The participants warmed up until they felt fully prepared to perform a vertical jump. They were then asked to stand on a force plate and perform trials of maximum effort standing vertical jumps. The take-off and landing forces produced while jumping were recorded for every trial. The participants were finished with the study and were free to leave the lab as soon as all of the data had been collected and recorded.

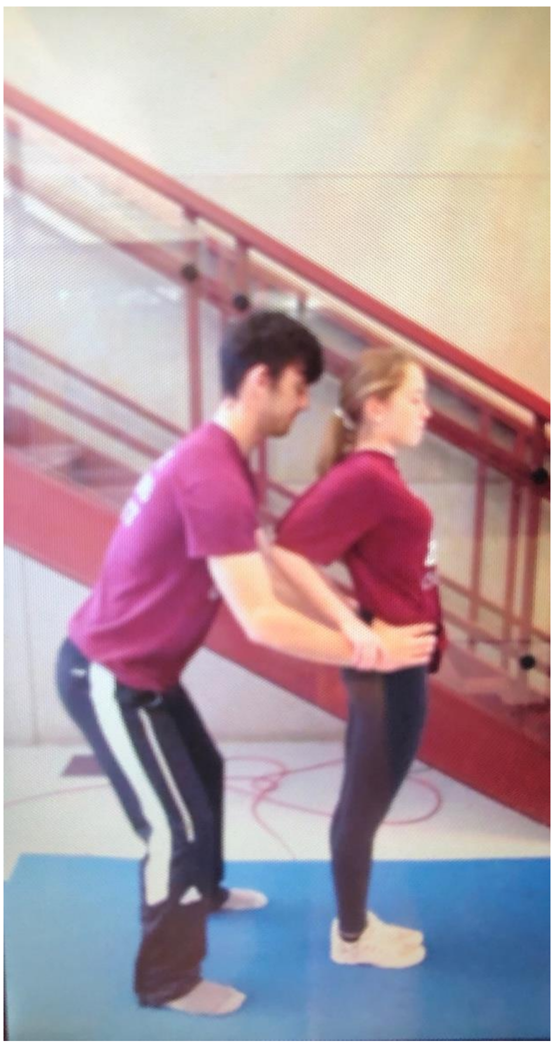

Image 1. The force plates and cheerleading set up.

Equipment

Force Plates

In order to measure the ground reaction forces encountered during both the take-off and the landing of the cheerleading stunts, two force plates were used. The two force plates were both RoughDeck by Rice Lake Weighing Systems USA. The reasoning behind using two separate force plates was to allow the base to stand on one plate while the flyer stood on the other to ensure that the individual forces specific to each member of the stunt group could be analyzed individually. The force plates were calibrated before each use and data was sampled at 2000 Hertz during the entirety of the stunt. The data was then stored using custom written LabVIEW software and a national instruments acquisition system. Later analysis was performed using Microsoft Excel.

Cheerleading Mats

In the study, two different cheerleading mats were placed on top of the force plates at different times in an attempt to compare the difference in the ground reaction forces based on the surface. The first cheerleading mat was an older mat that had a thickness of 3.81 centimeters. The second cheerleading mat, which was considered to be the good mat, was 4.45 centimeters thick.

Data Collection

Data was collected using custom-written LabVIEW software and a national instruments acquisition system. The data was sampled at 2000 Hertz. The graphs of the vertical ground reaction forces that resulted after every stunt were analyzed to determine the peak vertical ground reaction forces for each individual. These peak vertical ground reaction forces were documented. These were later used in order to compare the ground reaction forces to the body weight of each individual, to determine if a relationship could be found between the ground reaction forces and the type of surface, and to see if a difference was found in the ground reaction forces between the different stunts that were performed.

Project Objectives

The primary purpose of the experiment was to investigate the ground reaction forces on the take-off and landing of both the base and flyer when performing three basic cheerleading stunts, a basic toss, a toss to hands, and a toss to extension. This initial study was conducted in the hopes of sparking interest from other researchers to continue investigating different aspects of the sport of cheerleading. The study has filled gaps in the limited knowledge about cheer-related topics and has opened discussions for further research. It has helped those involved in the study and in the sport of cheerleading to better understand the location and amount of strain being placed on the body due to the ground reaction forces that are encountered when stunting. The analysis from this study will eventually be used to create programs to ensure that the cheerleaders' bodies are better able to handle encountering these large ground reaction forces, as well as to better injury prevention methods.

Results

Cheerleading Stunt Study

A study was performed in which four different bases and three different flyers from the Eastern Kentucky University cheerleading team came to the Moberly building on Eastern Kentucky University's campus. Each stunt pair performed two trials of a basic toss, a toss to hands, and a toss to extension. Any failed attempts, which included attempts in which the stunt group did not successfully complete the stunt and attempts in which the base and flyer both landed on the same force plate, were repeated until successful. The first trial was performed on the bare force plates and the second trial was performed on the force plates that were covered with the good cheerleading mat, which had a thickness of 4.45 centimeters. This was done in order to determine whether a difference could be seen in the vertical ground reaction forces that were encountered when stunting on different surfaces. The mean peak ground reaction forces and standard deviations for each person based on the stunt that was performed was determined (Table 1).

		N	Mean ± Standard Deviation (kg)
Flyer Take-Off Force	toss drill	6	115.8 ± 15.0
	toss hands	10	120.3 ± 17.9
	toss extension	10	125.1 ± 18.3
	Total	26	121.1 ± 17.2
Flyer Landing Force	toss drill	6	208.1 ± 76.0
	toss hands	10	266.0 ± 67.4
	toss extension	10	266.0 ± 67.7
	Total	26	252.6 ± 71.1
Base Take-Off Force	toss drill	6	237.4 ± 28.8
	toss hands	10	252.0 ± 32.8
	toss extension	10	272.2 ± 30.1
	Total	26	256.4 ± 32.8
Base Landing Force	toss drill	5	235.5 ± 60.6
	toss hands	10	256.5 ± 39.5
	toss extension	10	284.5 ± 86.8
	Total	25	263.5 ± 66.3

Table 1. The average and standard deviations of the data.

The average peak take-off and landing ground reaction forces were compared to the body weight of each individual participant in the study (Table 2). All of the average peak ground reaction forces that were encountered were over two times the body weight of the cheerleading participants. For the flyers that were included in the study, the average peak landing forces were more than five times their individual body weights.

Position	***Average Peak Take-Off Force Compared to Body Weight***	***Average Peak Landing Force Compared to Body Weight***
Flyer 1	*2.5*	*5.5*
Flyer 2	*2.3*	*5.3*
Base 1	*3.0*	*3.5*
Base 2	*3.0*	*2.4*

Table 2. Average peak take-off and landing forces compared to individual body weight.

The influence that the height and difficulty of the cheerleading stunt had on the average peak vertical ground reaction forces was investigated (Table 4). The only statistically significant difference in the average peak ground reaction forces was between the toss drill and the toss extension for bases on take-off. On average, the bases encountered larger ground reaction forces on the take-off of the toss extension than on the take-off of the toss drill. This indicates that the bases exert significantly more force when the flyer must be elevated to a greater height during a stunt.

Dependent Variable	(I) Stunt Type	(J) Stunt Type	Mean Difference (I-J) (lb.)	Sig.
Base Take-Off Force	toss drill	toss hands	-52.2	.179
		toss extension	-96.6*	.018
	toss hands	toss drill	52.2	.179
		toss extension	-44.4	.163
	toss extension	toss drill	96.6*	.018
		toss hands	44.4	.163

*. The mean difference is significant at the 0.05 level.

Table 3. Pairwise comparison of stunt type.

The surface on which cheerleaders perform varies greatly depending on the event at which they are participating. A previous study was conducted that investigated the critical heights of different cheer floorings as determined by the risk for brain injuries, but the vertical ground reaction forces were not determined for this study. Therefore, it is important to investigate whether a different type of floor impacts the ground reaction forces that are encountered. The results can then be analyzed further to determine if the results from this particular study are in agreement with the study of the critical heights of sports flooring and how the flooring, ground reaction forces, and injuries might all be related.

The average peak ground reaction forces of the flyers' landings were separated based on which stunt was being performed and whether the trial was being performed on the force plates with no mat or on the force plates that had a cheerleading mat placed on top (Fig. 2 and Table 3). When strictly looking at the graph, the average peak ground reaction forces of the flyers' landings appeared to be slightly less when performed on the cushioned cheerleading mat than when performed on the force plates without the mat. Despite this, when looking at the pairwise comparison between the mat setting for the bases and flyers, the difference in flooring was not found to be statistically significant for any of the take-off or landing ground reaction forces.

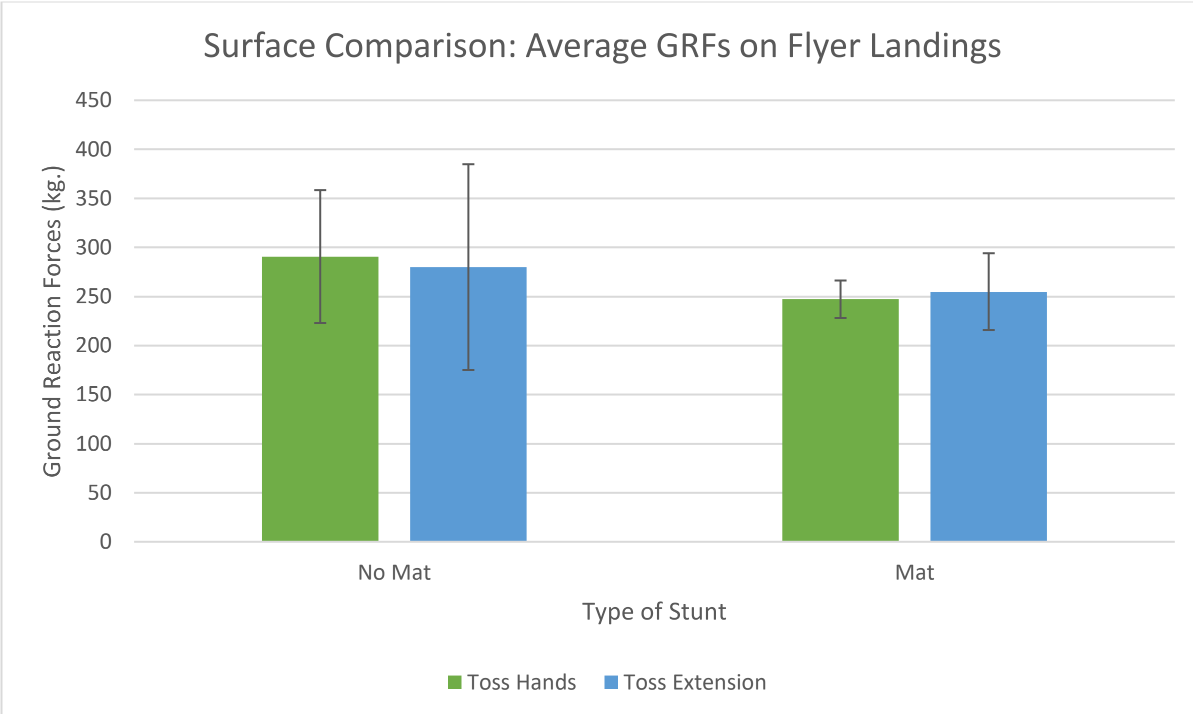

Figure 1. Average peak ground reaction forces on flyers' landings in comparison with stunting surface.

Flooring Study

Landing of Weights

The study of the cheerleading flooring is of particular interest, so, therefore, two other studies were conducted to further test the significance of flooring on the average peak forces. The first study was conducted by dropping two different weights, a shot put and a medicine ball, from heights of 1.02 meters and 2.95 meters onto the force plates. At least six trials were performed from each height with each different weight. The trials were repeated with the old cheerleading mat (3.81 cm thick) placed on top of the force plates and with the good cheerleading mat (4.45 cm thick) placed on top of the force plates. The peak landing forces of these objects were recorded.

The study that investigated the difference in the landing forces of two different weights when dropped onto varying surfaces ensured that every trial was performed exactly the same (Table 5). When investigating the landing forces of the shot put, the flooring did not have a statistically significant effect. On the other hand, the landing ground reaction forces of the medicine ball, which compresses more than the shot put upon landing, was found to differ significantly when comparing no mat to the bad mat and good mat. The bad cheerleading mat and good cheerleading mat both had significantly lower ground reaction forces for the medicine ball than when the medicine ball landed on just the force plates.

Dependent Variable	(I) Mat	(J) Mat	Mean Difference (I-J) (lb.)	Sig.
Medicine Ball Force	no mat	bad mat	164.5*	0
		good mat	111.8*	0
	bad mat	no mat	-164.5*	0
		good mat	-52.7	0.052
	good mat	no mat	-111.8*	0
		bad mat	52.7	0.052

*. The mean difference is significant at the 0.05 level.

Table 4. Pairwise comparison of dropping medicine ball on different surfaces.

Vertical Jump Testing

The second study that was conducted to look into the effect of the surface on ground reaction forces involved four members of the Eastern Kentucky women's soccer team. The participants were asked to perform trials of vertical jumps on the force plates. Once again, trials were performed on just the force plates, on the old cheerleading mat, and on the good cheerleading mat. The data was collected and analyzed for each trial of these studies.

The ground reaction forces encountered on the take-off and landing of vertical jumps of women's soccer players resulted in similar findings to those of the cheerleaders performing stunts. There were no significant differences found in the peak ground reaction forces of the different surfaces, but the difference in the landing forces between the bad mat and good mat is trending towards significance (Table 4).

Dependent Variable	(I) Mat	(J) Mat	Mean Difference (I-J) (lb.)	Sig.
Vertical Jump Landing Force	no mat	bad mat	697.4	0.112
		good mat	726.6	0.087
	bad mat	no mat	-697.4	0.112
		good mat	29.2	0.942
	good mat	no mat	-726.6	0.087
		bad mat	-29.2	0.942

*. The mean difference is significant at the 0.05 level.

Table 5. Pairwise comparison of vertical jump based on mat type.

Limitations

With only being able to measure the ground reaction forces of four different bases and three different flyers, it is difficult to draw decisive conclusions. If this study had included a larger sample of cheerleaders, included the performance of more trials of each stunt, or even included the performance of more stunts, better inferences could be made. Despite these limitations, this data is groundbreaking in that the topic has never been researched before. It achieves the goal of determining baseline numbers for the vertical ground reaction forces encountered when performing stunts, which will allow for further research to more easily be conducted in the future.

Final Conclusions and Future Research

There are significant ground reaction forces that are encountered when performing cheerleading stunts. Despite the flyers and bases encountering large forces on both take-off and landing, these average peak ground reaction forces were not found to vary based on the type of stunt that was being performed, except for the take-off force of the bases. The difference in the take-off force for bases when performing a toss extension was significantly larger than when performing the basic toss. The flooring on which stunts were being performed was also not found to result in a statistically significant difference in the ground reaction forces that were encountered by the individual cheerleaders. The average peak ground reaction forces when compared to the body weights of each individual participant indicated that, on average, the landing ground reaction forces of the flyers were over five times their body weight.

In comparison to the ground reaction forces encountered by gymnasts, the gymnasts generally averaged vertical ground reaction forces between five and thirteen times their body weights. These ground reaction forces were found to play a role in the commonality of lower body injuries of gymnasts (Slater, Campbell, Smith, and Straker, 2015, p. 50). The three stunts that were performed during this particular study on cheerleaders were very basic co-ed stunts, and yet the average peak landing forces of the flyers when compared to their body weights were still within the average range for gymnasts. Therefore, it is important to further investigate these ground reaction forces to determine whether a relationship can be found between the forces and the prevalence of certain injuries. The study should also be extended to more difficult stunts that are performed at greater heights to determine if even more significant ground reaction forces are encountered when performing these stunts.

The investigation of the ground reaction forces during the take-off and landing of women's soccer players' vertical jumps was used to further test the impact of cheerleading flooring on these forces. It was found that the difference in the ground reaction forces based on the type of flooring were not statistically significant. Similarly, when a shot put was dropped onto the different cheerleading surfaces, no significant differences in the forces were found based on the type of surface. On the other hand, the bare force plates did result in significantly larger landing forces when a medicine ball was dropped on them than when the medicine ball was dropped onto the old cheerleading mat and the good cheerleading mat. This is an interesting finding that future research could potentially look into to determine the reasoning behind this difference.

These preliminary tests can be used by future researchers to continue studying aspects of cheerleading. The study of ground reaction forces can be extended to include more collegiate cheerleaders, as well as cheerleaders from different age groups and skill levels. The study can also be extended to include stunt groups that are all-female or contain more than one base. It could also be extended by having each stunt group perform other stunts, especially stunts with a greater difficulty. The flooring could further be investigated by having trials of each stunt performed on cheerleading mats with different thicknesses. Instead of simply looking at just the body weight of the individual cheerleaders, the data from the Bod Pod system could be used, as well. This would allow researchers to compare how the body composition of an individual cheerleader affects the ground reaction forces that they encounter, as well as how the body composition of one group member affects the ground reaction forces of the other member.
The individual muscles groups that are being activated while stunting could be investigated through the use of surface electrodes, which would allow for a more accurate determination of

the location in which these vertical ground reaction forces are being applied. The injuries that occur while performing stunts could also be directly examined in an attempt to find a relationship between the ground reaction forces encountered by cheerleaders and their injuries. This information could then be used to create better exercise and injury prevention programs for cheerleaders.

The biomechanics of landing a stunt in cheerleading, or even a skill in gymnastics, is different from the landings in many other sports due to the restriction of the hip and knee angles upon landing (Slater, Campbell, Smith, & Straker, 2015, p. 50). These restrictions result in larger ground reaction forces being applied to the lower bodies of the individuals that are performing the stunts. Because of this difference from other, more typical jump landings, the creation of personalized programs that take into account these biomechanical restrictions and work to better enable to bodies of cheerleaders to handle the large ground reaction forces encountered when stunting is essential.

As can be seen, this original test is just a starting point for researching the ground reaction forces encountered by cheerleaders when performing stunts. The different avenues for research that branch off of this study are vast, and hopefully researchers will begin to conduct more studies to continue to fill gaps in the limited research that has been performed on the sport of cheerleading.

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