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Influence of Traditional and Nontraditional Entries on Figure Skating Jumps

Bryanna Nevius

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Influence of Traditional and Nontraditional Entries on Figure Skating Jumps

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Requirements for Commonwealth Honors in Physical Education with a Concentration in
Exercise Science

Bridgewater State University

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Abstract

The purpose of this study was to determine whether or not adding a non-traditional jump entry into a routine is more beneficial to the skater or if there is more value in performing the same jump with a traditional entry. Specifically, the study examined the kinematics of a non-traditional versus a traditional jump entry by looking at the angles of the hip, knee, and ankle joints at take-off and landing. Maximum jump height, airtime, and horizontal displacement were also examined. It was hypothesized that non-traditional entries would change jump kinematics when compared to the same jumps performed from traditional entries. Ten skilled figure skaters volunteered to participate in the study and each was videotaped performing five trials of either a double salchow or a double toe loop using a traditional entry and five trials of the same jump using a non-traditional entry. The collected data were analyzed with DartFish and a series of paired samples t-tests compared the ankle, knee and hip angles at take-off and at landing, maximum jump height, air time, and horizontal displacement between traditional and non-traditional entries. The significance level of .05 was adjusted using a Bonferonni correction. It was determined that the significant findings were that maximum jump height increased from 0.36 ± 0.14 m in the traditional entry to 0.44 ± 0.15 m in the non-traditional entry and the ankle demonstrated more plantar flexion at landing ($90.5^\circ \pm 8.6^\circ$) in the nontraditional jump than in the traditional jump ($85.7^\circ \pm 12.9^\circ$). These findings indicate that greater jump height may be a by-product of performing jumps with a more difficult take-off position and the non-traditional jump landing is different when compared to the traditional landing of those jumps because of the greater plantar flexion. Future research should be directed towards studying different aspects of jump difficulty to gain a better

understanding of the influence of traditional versus non-traditional entries jumps as a whole.

Jumping is one of the first basic movements that one learns to perform as a child. The skill is mastered fairly quickly and as the child grows, it often times becomes a valuable skill in many of the sports they participate in. Gymnastics, track and field, and figure skating are a few of the sports where jumping is not only a valuable skill, but a required one. Figure skating and its governing body, the United States Figure Skating Association, in particular state that three of the required elements in the ladies short program be jump elements, and allow a maximum of seven of the required elements in the ladies long program to be jumps (USFSA, 2013). These quantities essentially break down into more than half of the elements in both the ladies short and long programs being jumps. With jumping being such an important factor in this particular sport, a great deal of emphasis is placed on the skater's performance of their jump elements. Over the years, judges have also started to reward skaters for making a traditional jump more difficult. In other words, skaters will receive more points for a jump with a difficult entry than they would receive for the same jump with a traditional entry.

With the creative freedom that skaters have in terms of their jump entries and with the extra points as incentive, more often than not, a skater will perform a more difficult version of a traditional jump by varying the entry in an attempt to earn more points. However, this trend may become a cause for concern if skaters are not proficient at their non-traditional jump entries, yet they include them in the program in hopes that they will earn extra points anyways. This begs the question of whether or not it is worth the extra points to include a non-traditional jump entry if the skater is more skilled at performing the same jump with a traditional entry.

The purpose of this study was to determine whether or not adding a non-traditional jump entry into a routine is more beneficial to the skater or if there is more

value in performing the same jump with a traditional entry. Specifically, the study examined the kinematics of a non-traditional versus a traditional jump entry by looking at the angles of the hip, knee, and ankle joints at take-off and landing. Maximum jump height, airtime, and horizontal displacement were also examined. Skaters and coaches often increase jump level difficulty to earn extra points, however it was hypothesized that non-traditional entries would change jump kinematics when compared to the same jumps performed from traditional entries.

Review of Literature

Before the research in this study was performed, it was necessary to review previous works of literature that have examined similar aspects of jumping and specifically jumping in figure skating. The review of literature provided a basis on which to start the investigation into which take-off positions are more biomechanically effective for the skater. It specifically examined knee forces, jumps, and difficulty factors that affect jumps, jump differences in take-off, judging in figure skating, and scoring in figure skating.

Knee forces, jumps, and difficulty factors that affect jumps

Understanding the biomechanics of jumping is an extremely useful skill to have because it is one of the first basic movements that you learn as a child and it is also a component of many well-known sports. Knowing how jumps work biomechanically can be useful for many different reasons such as for physical therapy purposes, coaching an athlete on how to jump correctly, bettering an athlete's skill set, etc. There are a few different types of jumping that essentially can be categorized by their ultimate goals; vertical jumps, aiming for height; projectile jumps, aiming for distance; or jumps that attempt to attain both height and distance. Jumps can also be categorized by how they are performed; for example, jumps can take-off with two feet or land with two feet, take-off with two feet and land on one foot, take-off with one foot and land on the same foot (i.e. a hop), or take-off with one foot and land on the other foot (i.e. a leap). The actual stages that are performed in these types of jumps are takeoff, airtime, and landing. Studies have shown that the characteristics of these types of jumps actually remain stable over developmental stages of the body and over the differences in jump types. In other words the most basic characteristics of any kind of jump are essentially the same,

regardless of the subject's ability or the individual jump type (Haywood, 1993). Further evidence indicates that children, adolescents, and adults all have similar patterns of leg coordination (particularly the timing of extension of the ankle, knee, and hip joints) when participating in both long jumps and vertical jumps (Haywood, 1993).

A study conducted by Cleather, Goodwin, and Bull (2013) looked specifically at vertical jumping and in particular, the internal joint forces that are produced during vertical jumping as well as push jerking (an Olympic weightlifting move). The experimenters constructed an anatomically correct biomechanical model of the knee to measure these internal joint forces, which consisted of four segments that represented the foot, calf, thigh, and pelvis (Cleather, Goodwin, & Bull, 2013). The use of the three dimensional model was revolutionary because until this particular study all previous studies examining joint forces were conducted using two-dimensional models of the knee. They determined that the total internal joint force was equal to the addition of the different forces from multiple joints throughout the leg, including the ankle, patellofemoral, tibiofemoral, and hip joints. These internal joint forces were calculated by combining the muscle forces (cross sectional area of muscle times assumed maximum muscle stress) and the intersegmental forces (Cleather et al., 2013). According to the study the knee experienced mean peak loadings of 2.4-4.6 times body weight at the patellofemoral joint and 6.9-9.0 times body weight at the tibiofemoral joint. The anterior tibial shear force was 0.3-1.4 times body weight, and the posterior tibial shear force was 0.0-3.1 times body weight. The hip had a mean peak loading of 5.5-8.4 times body weight and the ankle 8.9-10 times body weight (Cleather et al., 2013). Specifically for the take off portion of the vertical jump, the numbers were as follows; the ankle force was 8.9 times body weight, the knee joint force was 14.1 times body weight

(patellofemoral (4.2 times body weight) + tibiofemoral (6.9 times body weight) + anterior tibial shear (.6 times body weight) + posterior tibial shear (2.4 times body weight)), the hip joint force was 5.5 times body weight, and the ground reaction force was 1.3 times body weight (Cleather et al., 2013). What these findings show is that the general forces within each joint were considered similar in the jumping and push jerking. This study also showed that forces found are lower than what was suggested by previous studies that only employed two-dimensional models of the knee.

The internal joint forces of jumps would be particularly relevant to a sport such as figure skating because it is a sport where jumping is one of the key elements in the athlete's routine, or program as it is called. Examining the joint forces could help the athletes and their coaches make the skater's jumps more successful by better understanding technique, preventing injuries, and increasing the success of the landing. Female figure skaters have two programs that they perform every competition, the short program, which lasts for a maximum of two minutes and fifty seconds and the long program which lasts for four minutes \pm ten seconds (USFSA, 2013). In each of these programs there are a multitude of required elements that the skater must include, many of which are jumps. In the short program specifically, the athlete must include the following; a double or a triple axel, one triple jump which must be preceded by a connecting step sequence, and a jump combination (either a double/triple or a triple/triple), which totals three jumps. The long program consists of many more jump options, specifically a maximum of seven, simply because the program is much longer and there are more options for the skater to choose from. In the long program the skater's guidelines are as follows; an axel type jump is required, a jump combination consisting of two jumps is the limit, however one three jump combination is permitted, two triples or

quads may be repeated, but one must be in combination with another jump, the number of jumps in a sequence is unlimited, and a maximum of two double axels are allowed (USFSA, 2013).

The options in each of these programs allow for the skaters to choose which jumps they are most comfortable putting into their program, as well as choosing which jumps will gain the most points for them. There are six jumps that every figure skater learns when they are first starting the sport and they are the axel, salchow, toe loop, loop, flip, and lutz. A jump's degree of difficulty is oftentimes personal preference however most skaters learn them in the order listed above. These jumps differ from each other the most in terms of the take off, however after that part of the jumping sequence has been completed, the rotation in the air as well as the landing is completely the same with all six jumps; they are all essentially hops, or jumps that are performed taking off from one foot and landing on the same foot or leaps, that are performed taking off from one foot and landing on the other foot.

Jump Differences in Take-off

Dr. Deborah King is a leading researcher in the field of biomechanics and figure skating and much of her current work is based in this area of research. In one of her recent studies she examined jump take offs, which can be described by the direction the skater is facing while gliding into the takeoff, the foot upon which the skater is gliding, the edge of the blade which the skater uses, and the part of the blade-edge or toe pick-the skater uses for takeoff (King, 2000). The take off is the distinguishing element in a jump because after the take off is complete, all jumps are identical in terms of the rotation and landing. The axel is probably the most diverse out of all of them because it is the only jump out of the six that takes off from a forward edge instead of a backward edge; this

difference causes the skater to perform an extra half rotation in the air. The jumps can be divided into two categories; toe jumps and edge jumps, which refer to the edge that is being skated on during the takeoff aspect of the jump. Jumps can also vary in rotation as well, meaning that there can be single, double, triple, quadruple, etc, rotations that can be performed for any given jump. Skaters learn these jumps sequentially and once they master a certain number of rotations, they can begin to add more rotations to the same jump.

According to USFSA (2013), the first jump that skaters generally learn is the axel, specifically the single axel, which can be characterized by the extra half rotation that the athlete must perform compared to the other five jumps. The axel is different from other jumps because of this extra half rotation, but also because skaters take off from a forward outside edge, which is uncharacteristic of all other jumps (Figure 1).

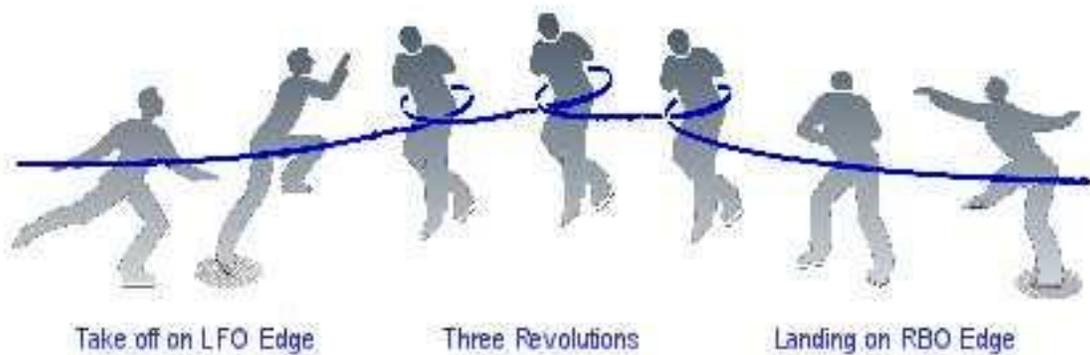


Figure 1: The triple axel jump [iceskate.net]

The next jump that skaters usually learn after the axel is the single salchow. This jump at its most basic level is characterized by its takeoff position, which is a backward inside edge. Once the skater is in the air, they complete one full rotation. With skill development the skater adds more rotations to complete jumps such as the double

salchow, the triple salchow, and the quadruple salchow (Figure 2).

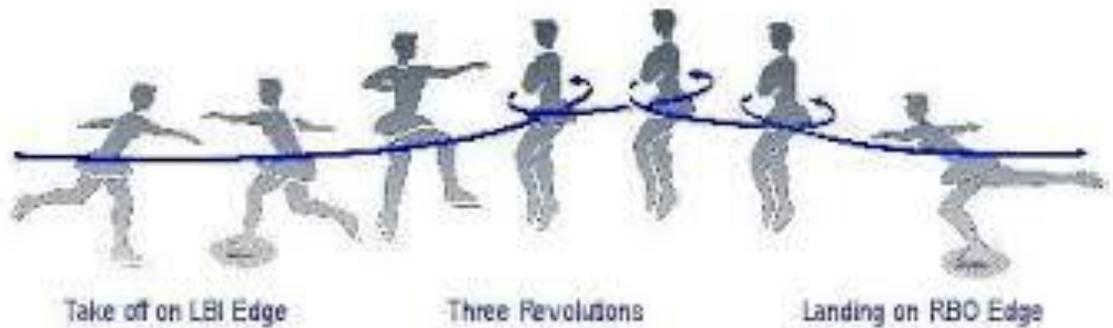


Figure 2: The triple salchow [iceskate.net]

The third jump that a skater will be taught is the toe loop, which is a toe jump as is stated in the name. The toe loop, unlike the axel and salchow takes off on two feet at first before it requires one foot. Essentially there is a transfer of weight that occurs from the back outside edge to the extended leg. As the skater glides on the backward outside edge, their weight is gradually transferred from that leg to the extended free leg with the toe pick in the ice. The skater will take off from the extended free leg with the toe pick in the ice, which is what makes this jump so different from the axel and the salchow (Figure 3).

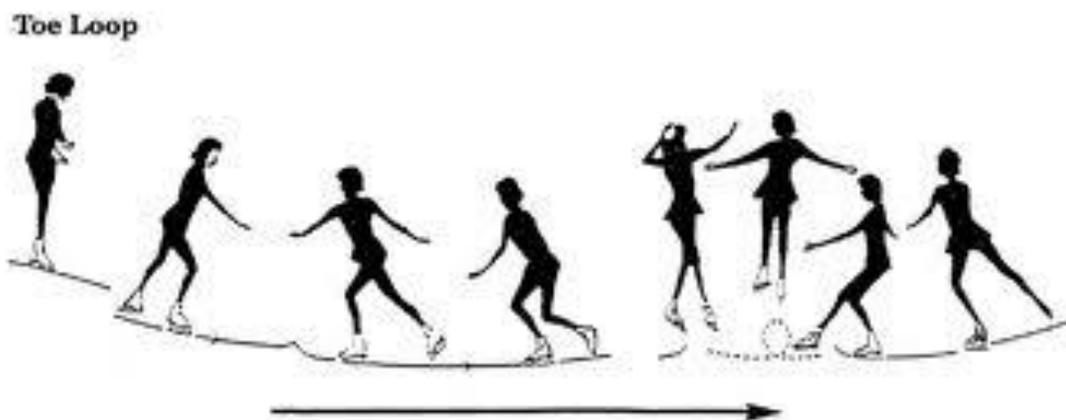


Figure 3: The single toe-loop [Martinez, C.]

These three jumps; the axel, salchow, and toe loop, are the first jumps that a skater will learn because they are the most basic jumps and the easiest for an athlete to pick up right away. The next three jumps, the loop, flip and lutz, are usually more difficult for a skater to learn, which is why they are the last three jumps that an athlete is taught. The flip and the lutz are both toe jumps, which makes them similar to the toe loop, however the loop jump is an edge jump, which makes it similar to the axel and salchow. The loop, flip, and lutz, while important to a skaters overall performance, are not the predominant jumps when first learning jumps, when skaters learn to add revolutions to previously learned jumps, or when changing the entry of the jump.

The completion, or the completion of the correct number of revolutions before landing, of the six jumps in figure skating is determined mostly by the skater's angular velocity at takeoff as well as flight time (King, 2000). Flight time can be defined as the amount of time (s) that a skater is in the air, from take off to landing, and angular velocity is the angular displacement in a given amount of time (angular displacement divided by time). Other factors that contribute to determining the completion of these jumps are jump height, knee, ankle, and hip joint patterns at take-off, and segmental angles during take off. In a study done by Johnson and King (2001), differences in triple and quadruple skating jumps were analyzed and data were taken from three elite athletes. Johnson and King got footage of triple and quadruple toe loops as well as triple and quadruple salchows from these three skaters. They measured variables such as jump height, time of jump, angular momentum at take off, moment of inertia at take off, minimum moment of inertia, angular velocity at take off, maximum angular velocity, horizontal velocity at take off, and vertical velocity at take off (Johnson & King, 2001). They found through the study was that it was necessary to have an increase in jump height, an increase in

rotation speed, or both for the athlete to successfully complete the jump (complete the correct number of revolutions and land the jump). Even though this study was strictly conducted while analyzing triple and quadruple jumps, it is conceivable that this study would apply to single and double jumps. This study also showed that an increase in angular velocity at take-off contributed to a successful completion of the jump as well as an increase in flight time. It also noted that a slower linear takeoff speed and differences in knee patterns might have contributed to a successful completion as well (Johnson & King, 2001).

As mentioned above, the number of revolutions performed in any skating jump is highly dependent upon flight time. Another study conducted by Fortin, Harrington, and Langenbeck (1997), which was concerned with using the biomechanics of figure skating to prevent injuries among athletes, also concluded that the number of revolutions performed in skating jumps was determined by flight time. It stated that the number of revolutions in a jump are determined by the jump height and the angular velocity. The authors analyzed five different elite male figure skaters and their performance of the axel jump (single and triple axel). Findings showed that the athlete's angular velocity for the completion of 1.5 revolutions (single axel) was 2.9 rev/sec and that the angular velocity for the completion of the 3.5 revolution triple axel, was 4.9 rev/sec (Fortin et al., 1997). They concluded that this increase in revolutions per second was attributed to an increase in angular momentum through an increased force production. Fortin et al. (1997) also stated that the biomechanics of all jumps are the same after the take off portion has been completed, which in other words, means that excluding the takeoff positions, all jumps are considered biomechanically identical (Fortin et al., 1997).

Judging Figure Skating Jumps

Jumping, as mentioned above, is one of the key elements in figure skating programs, which is why it is oftentimes the skater's main focus. Judges in figure skating are the sole determiners of how well a skater performs a jump and are the only ones awarding the athletes points; the sport is very subjective. In terms of points, jumps bring in the most points for a skater so it is also important to discuss the differences and similarities between a biomechanically accurate jump, and what the judges view as accurate. A study was conducted in 2006 by Lockwood, Gervais, and McCreary, that looked more closely at this subjective point of view of the judges and tried to determine if it was accurate, and if it was, how accurate. Due to the subjectivity of the sport, there have been issues in the history of figure skating where judges award an incorrect amount of points to certain skaters out of bias, human error, etc, so this study set out to determine the validity of the judging system. By evaluating the traditional method of scoring and comparing it to a biomechanical analysis of the same jumps, it created a better understanding in the world of figure skating as to whether or not judges were accurate in scoring the skater's jumps. This study began by collecting data from 52 figure skaters performing both double and triple jumps, however after reviewing the footage, ten of the recorded jumps were chosen based on the researchers' definition of biomechanical excellence. The criteria used to identify biomechanical excellence consisted of the landing technique, the landing edge quality, the geometry of the landing edge, and the geometry of the landing position (Lockwood et al., 2006). These same ten jumps were analyzed by forty two accredited judges using the same five categories mentioned above, however the team divided them into subcategories to collect as much detail from the judges as possible. The first category, overall landing performance, was divided into two

subsections; entire landing and completed rotations. The second category of landing technique upon initial contact was divided into four subsections; toe to edge sequencing, position, stability, and flow. The third category consisting of landing edge quality included subsections such as control, smoothness, sound and speed, however sound was omitted because the recordings of the jumps did not provide a clear sound for the judges to score. The fourth category was geometry of landing edge and there were three subsections that consisted of arc, length of landing arc, and alignment. The last category was geometry of body position, which had the most subsections including, skating leg action, free leg action, free leg extension, trunk position, arm position, and eye/head focus (Lockwood et al., 2006). The categories were extensive however the team wanted to complete the most accurate study possible with which to report their findings. When the results were initially compared to the biomechanical ratings, there was a strong association among the judges' perceived ratings of the ten jumps and there was a strong association between the judge's perceptions of the jump categories and their overall perceptions of landing performance. The researchers did find however, that there was a weak correlation between the biomechanical ratings (measured quantities) and the judges' perceptions of the jump performances, so they decided to regroup the data instead by strategies that were used by the athletes to achieve excellence in landing.

Biomechanical excellence was redefined as the employment of one of the following techniques used during the landing portion of the jump. The team defined the landing strategies as the sequence of movements or range of motion at the ankle, knee or hip (Lockwood et al., 2006). The hip strategy consisted of mostly hip movement and little movement of the support leg during the landing. The knee strategy consisted of a greater amount of knee movement when compared to hip movement and the shared

strategy was almost equal amounts of movement of the hip and the knee during landing (Lockwood et al., 2006). Any jumps that did not fit in with this newly established definition of biomechanical excellence were taken out of the study. With this new perspective, once the data were reanalyzed, there was a significant correlation between the judges' perceptions of excellence and the biomechanical definition of excellence. The final results of this study provide evidence that suggests that jump landings as evaluated by accredited judges are accurate when compared to a biomechanical analysis of the same jumps. This has extremely useful implications on the world of figure skating because it provides evidence that in most cases judges' perceptions of jump excellence are highly accurate when compared to the biomechanical perceptions of the same jumps.

Scoring In Figure Skating

The judges in figure skating follow a specific grading system that is similar in detail to the one discussed in the study above. USFSA (2013), the governing body of figure skating deems that all elements in a program are to receive a base value, or in other words, a certain amount of points just for attempting the element. Specific elements, in this case jumps, all have different base values however in addition to the base value, the judges are allowed to award an additional three points, or subtract an additional three points from every element in the program. A recent trend that has been emerging in the world of figure skating since the new judging system (which assigns a specific point value to every element performed in a skater's program) has replaced the 6.0 judging system (allowed judges to score every element in the program out of six points) rewards skaters for the degree of difficulty of the jump they perform. Specifically for jumps, the criteria that the judges use to base the awarding of extra points is provided by USFSA and consists of eight different "bullets" as they are called. They are as follows;

unexpected/creative/difficult entry, clear recognizable steps/free skating movements immediately preceding the element, varied position in the air/delay in rotation, good height and distance, good extension on landing/creative exit, good flow from entry to exit including jump combinations/sequences, effortless throughout, and the element goes to the musical structure (Cinquanta & Schmid, 2012). Based on these eight bullets, judges are allowed to add up to three points to the base score of every jump the skater performs. According to the judges' discretion, if the skater has completed two bullets, they are allowed to be rewarded with one extra point, if they complete four bullets, they are rewarded with two extra points, and if the skater performs six or more bullets, they are awarded plus three (Cinquanta & Schmid, 2012).

In an attempt to collect as many points as possible for each element they perform, skaters and coaches often try to make the jumps as interesting as possible by incorporating as many of these bullets as possible. Almost all skaters who are competitive incorporate some, if not most of these criteria into their programs at one point or another. The skaters will incorporate these bullets into jumps and elements that they find to be the easiest for them, which for most will be the axel, salchow, or toe loop jumps. The non-traditional entries will gain the athletes more points in competition if they are completed correctly, however if adding a difficult entry to a jump makes it more difficult for the skater to complete and they fall for example, then the attempt will not count at all. In other words if the skaters' base value for a triple salchow is a 4.2, and they have an unexpected difficult entry with preceding movements, they would potentially receive a 5.2 for the jump. However if the skater falls while attempting this salchow, then they will have three points subtracted from their score, which will give them a 1.2. In a case such as this it may be more beneficial to not attempt the additional

bullets in competition until the skater is proficient at performing the jump with potential for more points.

The new judging system provides skaters the opportunity to be more in control of how many points they earn for their programs. What is most appealing and tempting is the chance for skaters to receive extra points for completing a more difficult jump entry because one point can often be the difference between winning and losing, and qualifying or not qualifying. While it seems like a simple solution to add more bullets onto elements for the sake of collecting as many points as possible, it is important to look at the biomechanical advantages and disadvantages of adding so many extra movements to an element because they may prohibit the skater from performing a biomechanically excellent jump. In other words the extra fraction of a point the skater receives for adding bullets to the jump element may not outweigh the points received for a jump with no bullets if the non-traditional jump entry causes the skater to fall or not complete the jump correctly.

Summary

The number of extra points that figure skaters can attain by adding extra bullets into their routine is tempting considering the competition that the athletes face from their peers. However when it comes to adding bullets in the form of a more difficult jump entry, it is critical that the athlete look at the benefits from a biomechanical perspective before adding them into their routines. Research has shown that the completion, or completion of the correct number of revolutions before landing, of a jump is highly dependent upon factors such as angular velocity, flight time, internal joint forces during take off, and hip and knee strategies. Therefore, anything that may change these factors will have an effect on the rest of the jump, and essentially determine how successful it is.

Methods

Subjects

The participants that volunteered for this study were 10 female figure skaters from Massachusetts and Rhode Island who were able to perform both double salchows and double toe loops proficiently from both traditional take offs and a non-traditional take-off of their choice. The athletes were chosen by me through personal communication with their coaches and their parents. Before data collection began, all participants and the participant's parents (if under 18 years old) were asked to sign a University approved consent form stating that they agreed to be participants in this study.

Procedure

The data for this research were collected on three separate days in different locations, with different skaters. The same procedures were followed each day, however the only difference was the number of skaters being filmed during each session. Ten skaters in total participated in this research study and five skaters were filmed on the first day of data collection. Skaters arrived at the rink at approximately 8:15 am and filled out a University approved consent form as well as a demographic survey. After the paperwork was completed, the skaters placed joint markers on both sides of their legs at their hip, knee and ankle joints under my direction. At 8:50 am the skaters took the ice where they had 20 minutes to warm up before the filming began. During this time, I set up the necessary equipment which included two tripods and two cameras. One camera was placed in the hockey box and one was placed on the ice near the zamboni door. After the location of the cameras were chosen, a subject performed a double salchow and a double toe loop in front of the cameras to make sure that the camera's field of view was correct and that it captured the entire jump as well as to show the other subjects where to

perform their jumps in relation to the camera. After the locations were confirmed, filming began and all five skaters performed five trials of the jump they chose (double salchow or double toe loop) with a traditional entry. Once these trials were completed, the skaters then performed the same jump five times with a non-traditional entry. During the filming of all of the subjects' non-traditional entries, a third camera was used to capture the entire entry and take-off position. On the second day of filming a very similar procedure was followed however only one subject was filmed during this day. The third day of filming was similar procedurally to both the first and second days. Four skaters were filmed performing the jump of their choice for five trials with both traditional and non-traditional take-offs and a third camera was used in these non-traditional trials as well.

Data Collection and Analysis

During the study a standard video-tape (Cannon digital camera ZR960) as well as two digital cameras (Nikon Cool Pix S6100 and Sony Cybershot DSC-S750) were used to collect data from the skaters during their practice sessions. Once all of the data were collected from the three days, they were uploaded onto the computer with DartFish software where they were further analyzed. Using DartFish each of the skater's trials, both traditional and non-traditional, were analyzed specifically in terms of the take-off angle of the ankle, knee, and hip joints (Figure 4), the maximum jump height, airtime, horizontal displacement, and the landing angle of the ankle, knee, and hip joints (Figure 5).



Figures 4: Take-off Angles [Wikibooks.org] Figure 5: Landing Angles [Oocities.org]

Take-off positions for the toe loop were defined as the last backward movement where both feet were still in contact with the ice and the take-off position for the salchow was defined as the last backward movement when the full blade was in contact with the ice. Jump height was found by measuring the highest point in the air the skater reached to the ice surface and subtracting her height from that value and horizontal displacement was defined as the distance from the moment the skater's blade left the ice at take off to the moment the toe-pick first made contact with the ice at landing. Airtime was defined by the time between the take-off position and the landing position, approximately when the skater's blade left the ice to when it first landed on the ice again.

Data were then analyzed with DartFish ProSuite V 6.0 and entered into Excel 2008. A series of paired samples t-tests compared the ankle, knee and hip angles at take-off and at landing, maximum jump height, airtime, and horizontal displacement between traditional and non-traditional entries. Entries for all jumps, just toe loops, and just salchows were compared and the significance level of .05 was adjusted using a Bonferonni correction. In total there were one hundred trials analyzed (ten trials per skater), however some trials that were videotaped had to be excluded because of falls or step outs, leaving 43 trials for analysis.

Results

Subjects

The subjects, whose data can be seen in Table 1, consisted of ten female figure skaters who were able to perform either a double salchow or a double toe loop from both a traditional entry and a non-traditional entry of their choice. The subjects volunteered to participate in the study and they signed an informed consent form stating this agreement. Of the ten skaters, one was at the pre-juvenile level, three were at the juvenile level, three were at the intermediate level, one had passed novice, and two were seniors. Almost all of the subjects practiced all jumps from traditional entries (eight subjects), one subject practiced axel, double salchow, double flip and double lutz with traditional entries and one subject practiced axel, double salchow, double toe loop, and double loop from traditional entries. In terms of jump performance with non-traditional take off positions, three skaters perform the axel, five skaters perform a double salchow, six skaters perform a double toe loop, four perform double loops, five perform double flips, and three perform double lutzs. Skaters were asked in the demographic survey when they felt comfortable practicing either the double salchow or double toe loop with a non-traditional take-off position. Six skaters said when they were consistent with landing the jump, two skaters said always, one skater said one year prior, and one skater said when they tested up to the level below what they are now.

Table 1. *Subject Demographics*

| | Age (yrs) | Height (m) | Weight (N) | Skating Experience (years) | Hours/Week |
|--------------------|-----------|------------|------------|----------------------------|------------|
| Mean | 15.2 | 1.5 | 447.0 | 10.2 | 6.6 |
| Standard Deviation | 3.7 | 0.09 | 90.2 | 3.6 | 3.9 |

Take-off angles

The results of the jump take-off measurements analyzed with Dartfish are presented in Table 2. Overall jumps and in the toe loop and salchow there were no significant differences between traditional and non-traditional entry take-off angles for the ankle, knee, or hip. There were however almost significant findings for the ankle and hip joints at takeoff. For the angle of the ankle at take-off the mean was 81.8 ± 11.3 degrees for traditional trials and 84.5 ± 7.8 degrees for non-traditional trials ($p=.023$); this shows slightly more plantar flexion in non-traditional trials. The hip joint angles at take-off for traditional trials were 127.4 ± 16.1 degrees and 132.3 ± 22.1 degrees or non-traditional trials ($p=.028$). This shows slightly more hip extension during non-traditional trials.

Table 2. *Comparison of Traditional (T) with Non-Traditional (NT) Take-off Angles*

| Jump | Ankle T | Ankle NT | Knee T | Knee NT | Hip T | Hip NT |
|---------|-----------------|----------------|------------------|------------------|------------------|------------------|
| Toe | | | | | | |
| Loop | 83.6 ± 10.6 | 86.6 ± 8.9 | 126.6 ± 18.1 | 128.8 ± 19.2 | 127.8 ± 21.1 | 135.5 ± 28.6 |
| Salchow | 79.8 ± 12.0 | 82.5 ± 6.1 | 125.9 ± 5.8 | 122.7 ± 7.83 | 126.9 ± 8.1 | 129.2 ± 13.5 |
| All | | | | | | |
| Jumps | 81.8 ± 11.3 | 84.5 ± 7.8 | 126.3 ± 13.6 | 125.7 ± 14.7 | 127.4 ± 16.1 | 132.3 ± 22.1 |

Note: all measures in degrees; Traditional=T Non-Traditional=NT

Bonferroni Correction $p < .005$

Flight

The results of the flight time measurements analyzed with Dartfish are presented in Table 3. In all jumps, the only significant difference during flight was the maximum jump height. The mean for the traditional jumps was $.36 \pm .14$ m while the non-traditional mean was $.44 \text{ m} \pm .15 \text{ m}$ ($p=.001$). In the toe loop particularly there was a significant difference in jump height where the mean for the traditional toe loop was $.33$

$\pm .13$ m while the nontraditional mean was $.45 \pm .17$ m ($p=.0005$). In the salchow, there was only a significant difference in the horizontal displacement of the jumps. The traditional salchow mean was $1.56 \text{ m} \pm .64$ m while the non-traditional salchow had a mean of $1.83 \text{ m} \pm .72$ m ($p=.001$).

Table 3. *Comparison of Flight: Traditional (T) versus Non-Traditional (NT) Entries*

| Jump Type | Max Jump Height T (m) | Max Jump Height NT (m) | Airtime T (s) | Airtime NT (s) | Horizontal displacement T (m) | Horizontal displacement NT (m) |
|-----------|-----------------------|------------------------|---------------|----------------|-------------------------------|--------------------------------|
| Toe Loop | $0.33 \pm .13^*$ | $.46 \pm .171^*$ | $.62 \pm .07$ | $.63 \pm .11$ | $1.31 \pm .53$ | $1.04 \pm .17$ |
| Salchow | $.38 \pm .14$ | $.43 \pm .117$ | $.78 \pm .12$ | $.77 \pm .09$ | $1.56 \pm .64^*$ | $1.83 \pm .72^*$ |
| All Jumps | $.36 \pm .14^*$ | $.44 \pm .145^*$ | $.69 \pm .12$ | $.70 \pm .12$ | $1.43 \pm .59$ | $1.45 \pm .66$ |

Note: *= Significant difference at $p= <.005$

Landing Angles

The results of landing angles analyzed with Dartfish are presented in Table 4. There were significant differences in all jumps for the ankle angle at landing where the mean for traditional trials was 85.7 ± 12.9 degrees and the mean for non-traditional trials was 90.5 ± 8.6 degrees ($p=.001$). There were also significant differences found for the angle at the ankle joint toe loop jumps, where for traditional trials the mean was 83.9 ± 12.5 degrees and the non-traditional mean was 88.7 ± 9.12 degrees ($p=.001$). This shows greater plantar flexion during non-traditional trials at landing versus traditional trials at landing.

Table 4. Comparison of Traditional (T) with Non-Traditional (NT) Landing Angles

| Jump | Ankle T | Ankle NT | Knee T | Knee NT | Hip T | Hip NT |
|---------|------------------|-----------------|-----------------|-----------------|------------------|------------------|
| Toe | | | | | | |
| Loop | 83.9 \pm 12.5* | 88.7 \pm 9.1* | 135.1 \pm 6.3 | 135.8 \pm 7.9 | 129.5 \pm 14.4 | 136.1 \pm 14.7 |
| Salchow | 87.5 \pm 13.2 | 92.2 \pm 7.9 | 134.6 \pm 8.7 | 129.3 \pm 9.5 | 128.2 \pm 19.6 | 133.4 \pm 15.2 |
| All | | | | | | |
| Jumps | 85.6 \pm 12.9* | 90.5 \pm 8.6* | 134.8 \pm 7.4 | 132.5 \pm 9.2 | 128.9 \pm 16.9 | 134.7 \pm 14.8 |

Note: All measures in degrees; Traditional=T Non-Traditional=NT

*= Significant difference at $p < .005$

Discussion

The purpose of this study was to determine whether or not adding a non-traditional jump entry into a routine is more beneficial to the skater or if there is more value in performing the same jump with a traditional entry. Biomechanical effectiveness was examined by measuring the angles of joints at take off and landing as well as measuring jump height, horizontal displacement, and flight time. It was hypothesized that non-traditional entries would change jump kinematics when compared to the same jumps performed from traditional entries.

Take-off Position

There were no significant differences that were found during the take-off portion of the jump for traditional and non-traditional jump entries. However, there were almost significant findings for the angle of the ankle at take-off, indicating more plantar flexion in non-traditional trials. This may indicate that during traditional take-off positions the skater has more time to dorsiflex the ankle joints to prepare for the jump than they do in non-traditional trials. Studies have shown that knee and other joint patterns contribute to successful completion of the jump, meaning that the knee and other joint patterns help contribute to more successful landings (Johnson & King 2001), suggesting that the decrease in plantar flexion of the ankle joint in traditional jumps might allow for a more successful completion of that jump. It could also suggest that the skater is further along timing wise in their jump during non-traditional trials (i.e. the dorsiflexion of the ankle may be complete and it is now plantar flexing).

There were also almost significant findings for the hip joint angle at take-off where there was more hip extension during non-traditional trials of all jumps compared to traditional trials. This hip extension during non-traditional trials of all of the jumps may

indicate that during traditional trials the skater is able to flex the hip joint more than they were able to during non-traditional trials of those jumps. Like the ankle findings, more hip joint extension during non-traditional trials at take-off could also suggest that the skater has already flexed the hip and is now extending it. The hip flexion in traditional jumps may be a result of traditional constraints in terms of technique that are placed on the skater while performing the traditional entry. This change in the hip take-off angle could influence the landing.

Flight

When toe loop and salchow jump trials were combined, there were significant findings during flight as well. Maximum jump height was greater for non-traditional trials of all jumps when compared to traditional trials of all jumps. These findings indicate that greater jump height may be a by-product of performing jumps with a more difficult take-off position.

There were significant findings during flight in the toe loop particularly. There was a significant difference in jump height where the non-traditional trials were higher than the traditional entry trials. There were also significant findings in the salchow trials as well; the non-traditional horizontal entry provided for greater displacement than the traditional entry.

These significant findings for jump height during all jumps are most likely influenced by the significant findings for maximum jump height during toe-loop trials. Both the toe loop trials and the all jump findings show significant differences in maximum jump height. This could suggest a relationship between jump height and the technique associated with the toe loop jumps, especially during non-traditional trials. To perform a toe loop from both a traditional and a non-traditional take-off position, the

skater applies most of their weight on their favored leg and places the toe-pick of their free leg into the ice, which helps to propel them into the air. This movement essentially slows the horizontal portion of the jump to increase the vertical movement of the jump, which could be the cause of the increased jump height in the toe-loop versus the salchow. The increased jump height in the toe loop during non-traditional entries could be related to a lack of technical limitations associated with the traditional take-off position.

The significant findings in the salchow trials for horizontal displacement were also likely caused by the jump's specific technique. The salchow is an edge jump, meaning that the toe-pick is not utilized at all during take-off, which allows for more horizontal movement versus jumps that utilize the toe pick, such as the toe loop. Due to this variation in jumping technique, the horizontal speed of the salchow is not decreased as it was in toe loop trials, perhaps allowing for an increase in horizontal displacement with a non-traditional entry. Non-traditional entries may be more effective at creating a greater horizontal distance for edge jumps.

Landing Position

During the landing portion of the jump, there were significant differences in all jumps for the ankle angle, which showed greater plantar flexion during nontraditional entries when compared to traditional entries. There were also significant differences for the angle of the ankle joint during toe loop trials, which also showed greater plantar flexion at landing from non-traditional entries compared to traditional entries.

The increased plantar flexion at the ankle in all jumps during non-traditional trials is most likely due to the increased plantar flexion in the toe loop. This may indicate that the significant difference in the angle of the ankle during the toe loop and all jumps may be caused by the significant height difference found in the toe loop and all jumps. These

two jump characteristics may be related to each other and they suggest that the increased height during non-traditional trials may allow for the ankle to plantar flex in an effort to stabilize the landing portion of the jump. In addition to the jump height, jump timing may also be related to the increased plantar flexion. The non-traditional jumps seem to have a less structured technique throughout the jump because they do not have to start with a specific take-off position like the traditional jumps do. This may permit the jump to attain a larger maximum height, and consequently greater plantar flexion at the landing.

Summary and Recommendations

The purpose of this study was to determine whether or not adding a non-traditional jump entry into a routine is more beneficial to the skater or if there is more value in performing the same jump with a traditional entry. With the current judging system used to score jumps in figure skating many skaters and their coaches implement non-traditional take-off positions into the jump in order to earn more points during competition. The opportunity to earn extra points is appealing when as little as one tenth of a point can define how well an athlete performs. Skaters and coaches often increase jump level difficulty to earn extra points, however it was hypothesized that non-traditional entries would change jump kinematics when compared to the same jumps performed from traditional entries.

Significant differences were found in all jumps for jump height, horizontal displacement and the angle of the ankle during landing, with nontraditional trials being greater for all three aspects of the jump. Differences were expected between traditional versions of jumps and non-traditional versions of the same jumps, however these specific differences were not anticipated. While unanticipated the differences do highlight the fact that non-traditional jump entries do cause differences in the jump when compared to the traditional entry of the same jump. Increased plantar flexion during the landing is most likely caused by the increase in jump height during non-traditional trials. This increase in jump height may cause more difficulties in terms of the amount of control the skater has over the jump verses the amount of control they have over the traditional version of the jumps. Increased horizontal displacement during non-traditional trials may have the same effect.

These particular findings do seem to support the hypothesis; nontraditional jump entries did cause a change in the jump kinematics when compared to traditional entries of the same jumps. Almost significant findings were seen during take-off when measuring the angle of the ankle and hip. Both the angles of the hip and the ankle increased almost significantly during the take-off portion of non-traditional trials. This suggests that during traditional trials, skaters had more confined take-off positions, meaning that their hip and knee joints were flexed more, allowing them to prepare for the jump differently when compared to non-traditional trials.

The findings of this study could be further supported through a larger sample size as well as through acquiring the score given to the jump from an accredited figure skating judge. This would allow further insight into which jump take-off is more effective at earning more points from the perspective of the skater and the coach. In addition to the previous improvements, future research should be directed towards studying different aspects of jump difficulty other than just take-off positions to gain a better understanding of traditional versus non-traditional jumps as a whole.

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Appendix A

Bridgewater State University Parental Consent Form

Title of Research: Jumps in Figure Skating

Researchers: Dr. Pamela Russell and Bryanna Nevius

You are being asked permission for your child to participate in research. For you to be able to make an informed decision about whether you want your child to participate in this project, you should understand what the project is about, as well as the possible risks and benefits. This process is known as informed consent. This form describes the purpose, procedures, possible benefits, and risks. It also explains how your child's personal information will be used and protected. Once you have read this form and your questions about the study are answered, you will be asked to sign it. This will allow your child's participation in this study. You should receive a copy of this document to take with you.

Explanation of Study

This study is being done to better understand the advantages or disadvantages of changing the take off position/adding extra movements before the take off of the axel, salchow, and toe loop, in the hopes of earning extra points. It seeks to help coaches and skaters make the best decision of how to earn the most points during competition. If you agree to let your child participate in this study, they will be asked to choose a specific jump that they feel most comfortable with changing the entry. Your child will be asked to perform the jump with a "traditional" entry as well as a "non-traditional" entry while being video taped. This videotape will be viewed only by the research team and an accredited figure skating judge. Your child's participation in this study will last for approximately one hour during a scheduled ice session.

Risks and Discomforts

No risks or discomforts are anticipated

Benefits

This study is important to science because it will add to a growing population of research on the biomechanics of figure skating as well as help the scientific community better understand the sport of figure skating and the science associated with it. The study will also benefit the skating community by looking at the new judging system (specifically extra points awarded to jumps with more difficult take-off positions) and whether or not making a jump "more difficult" with advanced take-off positions is worth the extra points that a skater may gain from it. By better understanding the science behind the jumps, skaters and coaches can make more informed decisions on what they should and should not include in their programs. Individually, your child will benefit from being part of new research on the sport of figure skating and they may also be able to make better decisions when it comes to what type of take off positions are going to earn them the most points in competition.

Confidentiality and Records

Your child's study information will be kept confidential, meaning that only the immediate researchers and an accredited figure skating judge will be viewing the tape. The video footage will be stored securely in the laboratory computer and only the research team will have access to it. Also while every effort will be made to keep your child's study-related information confidential, circumstances may arise where this information must be shared with:

- * Federal agencies, for example the Office of Human Research Protections, whose responsibility is to protect human subjects in research;
- * Representatives of Bridgewater State University, including the Institutional Review Board, a committee that oversees the research at BSU;

Contact Information

If you have any questions regarding this study, please contact:

Bryanna Nevius
bnevius@student.bridgew.edu
774-266-3747

Dr. Pamela Russell
prussell@bridgew.edu

If you have any questions regarding your child's rights as a research participant, please contact The Institutional Review Board, Bridgewater State University, (508.531.2154)

By signing below, you are agreeing that:

- you have read this consent form (or it has been read to you) and have been given the opportunity to ask questions and have them answered
- you have been informed of potential risks to your child and they have been explained to your satisfaction.
- you understand Bridgewater State University has no funds set aside for any injuries your child might receive as a result of participating in this study
- you are 18 years of age or older
- your child's participation in this research is completely voluntary
- your child may leave the study at any time. If your child decides to stop participating in the study, there will be no penalty to your child and he/she will not lose any benefits to which he/she is otherwise entitled.

Parent Signature

Date

Printed Name

Child's Name

Bridgewater State University Child/Minor Assent

I understand that my parent or guardian has given permission (said it is okay) for me to take part in this study about jumping in figure skating under the direction of Bryanna Nevius and Dr. Pamela Russell. I am taking part because I want to, I have been told that I can stop at any time I want to, and nothing will happen to me if I want to stop.

Appendix B

Research Survey

Title of Research: Jumps in Figure Skating

Researchers: Dr. Pamela Russell and Bryanna Nevius

Name

Age

Height

Weight

How long have you been skating for?

What is your most recent test level passed?

How many hours a week do you practice?

During a typical practice session, what jumps do you practice with “traditional” take-off positions? How often?

When were you comfortable with changing the take off position of your jumps to potentially earn more points in competition?

During a traditional practice session, what jumps do you practice with “non-traditional” take-off positions? How often?