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A Kinematic and Vertical Ground Reaction Force Analysis of Skateboarders with Varying Years of Experience Performing the Kickflip Maneuver

Nicole S. Jacobs

BARRY UNIVERSITY

SCHOOL OF HUMAN PERFORMANCE AND LEISURE SCIENCES

A KINEMATIC AND VERTICAL GROUND REACTION FORCE ANALYSIS OF SKATEBOARDERS WITH VARYING YEARS OF EXPERIENCE PERFORMING THE KICKFLIP MANEUVER

BY

NICOLE S. JACOBS

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ABSTRACT

A Vertical Ground Reaction Force and Distribution of Net Joint Moments of Lower Extremity Joints Analysis of Skateboarders with Varying Years of Experience Performing the Kickflip Maneuver

By Nicole Jacobs

Thesis Committee Chair: Dr. Kathryn Ludwig
Department of Sport and Exercise Sciences

The purpose of this study was to begin to fill the gap of information that exists in biomechanically quantifying the sport of skateboarding. Skateboarding has several million regular participants in the US alone and a relatively high incidence of injury (Kyle *et al.*, 2002). Many of these injuries are the result of un-controlled landings and what can be assumed take-off forces produced to accomplish certain maneuvers. With 13 million people averaged to be skateboarders there is a gap in information related to quantifying this sport. In this current study, focus was geared towards the maximal take-off forces generated by the kickflip maneuver as well as looking at net joint moments produced. Three male skateboarders with less than 2 years of experience and three male skateboarders with more than 2 years experience participated. A multi-component force plate (AMTI 4507) was used. The plate recorded data in the Z axis for vertical force. Ground reaction forces were recorded directly into the computer program through an A/D converter. The ground reaction forces were amplified (SGA6-4) with a gain set at 4000 Hz. The skateboarders were asked to perform a successful kickflip maneuver on the force platform while on their skateboards. Peak forces were computed to compare the two groups of experience levels in the take-off phase only. Lower extremity kinematics were also calculated to provide body orientation in the air at take-off phase. Shared positive contribution (SPC) was also calculated to show the intersegmental coordination of the lower limbs. One-way MANOVAs were used to calculate; range of motion of the hip, knee and ankle; the hip, knee and ankle take-off angles; and the SPC of the hip to knee, and the knee to ankle. The vertical ground reaction force was statistically determined by a univariate ANOVA. Results found no significance difference in the above parameters but trends were discovered.

CHAPTER 1

Introduction

Epidemiological studies characterize skateboarding as an activity with a relatively high incidence of injury (Kyle, Nance & Rutherford (2002); Osberg, Schneps, Di Scala, Li (1998)). Given these clinical concerns and the fact that this sport has an estimated participation level of 13 million in the United States alone, it is surprising that so little is known about the biomechanics of this growing sport. Similarly a study done by Everett, 2002, reported high incidences of injury. The study reported incidences of injury at the emergency department near a local commercial skate park in California. Over one year, 102 episodes were recorded, representing 106 injuries. There was incidence of musculoskeletal injuries, which accounted for 80% of the visits to the emergency department, fractures and dislocations, and facial and abdominal injuries. A substantial number of injuries occurred at the skate park, despite controlled conditions and equipment requirements. This information raises the question of technique of the skateboarders and if proper instruction and training was known and given, and whether the future of the skateboarder's health and the life of the sport can continue with minimized risk and increase in performance value of the skateboarders.

Skateboarding was first started in the 1950s, when all across California surfers got the idea of trying to surf the streets. No one really knows who made the first board -- instead, it seems that several people came up with similar ideas at the same time. Several people have claimed to have invented the skateboard first, but nothing can be proved, and skateboarding remains a strange spontaneous creation. The earliest skateboards first appeared in the 1950s.

Many of the early boards were toy scooters whose handlebars had been removed. Other homemade skateboards were steel-wheeled roller skates nailed onto a piece of wood. It wasn't until the 1950's, when the surfing craze was in full swing, that people realized skateboarding could recreate the feeling of riding a wave. This connection with surfing gave skateboarding a direction that would influence everything to come, from maneuvers and style, to terrain, fashion and attitude. It was during this time that modifications were made to the trucks making it easier to maneuver. By 1959 the first Roller Derby Skateboard was for sale.

The first commercially produced skateboards appeared in the early 1960s, when Makaha Skateboards established a successful business. The Makaha Company later developed the tail or the backend curvature of the skateboard. In the early 1960's companies such as Larry Stevenson's Makaha and Hobie Alter's Hobie began to mass-produce the first true surfing-inspired skateboards. Some of the early proponents of surf-style skateboarding included Bill and Mark Richards, Dannu Bearer, Bruce Logan and Torger Johnson. Skateboarding became very popular almost overnight, and companies were fighting to keep up with demand. Over fifty million skateboards were sold within a three year period, and the first skateboard contest was held in Hermosa Beach, CA in 1963. Then in 1965 a slew of so-called safety experts pronounced skateboarding unsafe - urging stores not to sell them, and parents not to buy them. The skateboarding fad died as quickly as it had started, and the sport entered its first slump. Skateboarding would experience other slumps in its history. This pattern of peaks and valleys would come to be known as the "ten-year cycle," although the slumps weren't exactly ten years apart.

By the 1970s, skateboard design had advanced, and the models produced were much more safe than those of earlier years. This was because companies were making wheels, trucks, and other parts specially designed for skateboards. For many years skateboard construction varied among manufacturers, as plastic, fiberglass, metal, and wood were tested as deck materials, but by the late 1970s wood had won out as the optimum material. Decks constructed of seven-ply laminated wood tended to be lighter and stronger than those made of other materials. Curved plywood ramps designed for skateboarding were first used in 1975 in Melbourne Beach, Florida. Florida was the site of several other firsts in the sport, including the first skateboard park, Skatboard City in Port Orange, Florida, which opened in 1976. In the spring of 1975, skateboarding took an evolutionary boost toward the sport that we see today. In Del Mar, California, a slalom and freestyle contest was held at the Ocean Festival. That day, the Zephyr team showed the world what skateboarding could be. They rode their boards like no one had in the public eye, low and smooth, and skateboarding was taken from being a hobby to something serious and exciting. The Zephyr team had many members, but the most famous are Tony Alva, Jay Adams and Stacy Peralta.

Skateboarding remained popular in the 1980s and early 1990s, and the mid-1990s saw a fresh appreciation for the activity, especially as a competitive sport. A solid international competition circuit developed, leading to television broadcasts and a strong international market for the skateboard industry. The attention given to skateboarding in extreme sports competitions, such as the X Games, has also brought new fans to the sport.

A Kickflip is thought to be the most difficult of the basic maneuvers/tricks used by skateboarders. The maneuver is complex and precisely coordinated. To execute the kickflip the skateboarder must begin with an Ollie, and then flick the board with the foot to make it spin underneath while in the air. In a clean kickflip, the skater kicks the board with the top and side of his or her front foot, the skateboard flips and spins over at least once, and the skateboarder lands on the skateboard comfortably, wheels down, and rides away. (all previous historical info retrieved from skateboard.about.com/od/skateboardinghistory/Skateboarding_History.htm & www.wisegeek.com/what-is-the-history-of-skateboarding.htm)

Among the few biomechanical studies on skateboarding reported that resulting vertical ground reaction forces (VGRF) observed during the performance of an Ollie take-off have a characteristic two-humped shape (Frederick et al, 2006). Vertical ground reaction force values provide information as to how much force the subject is placing downwards in order to produce the action. These force values may not always predict the subject's overall jumping ability, strength, muscle mass and training regimen are also determinants to a subject's jumping ability. Fredrick and Determan did not describe the technique of the Ollie or the kickflip, which leaves a substantial hole in knowledge of how these tricks are accomplished.

Statement of the Problem

There have been limited studies done on the biomechanics of skateboarding techniques. Of those, none have examined the kinematics paired with the ground reaction forces.

Purpose of the Study

The purpose of this study was to provide an analysis of the kickflip ground reaction forces (GRFs) and kinematics of the body upon successful completion of the task as a way to provide information on the technique of novice and experienced athletes. An additional purpose was to compare the pattern of intersegmental coordination in executing a kickflip. In addition, this study also examined the forces in the vertical direction at take-off to provide data to reduce injury enhance performance and promote longevity in the sport.

Significance of the Study

The significance of this study is its utility as an informational tool for those interested in equipment development and those who wish to enhance performance of the kickflip maneuver. It was conducted to fill a void in information on the ever growing sport of skateboarding.

Limitations

This study was subject to the following limitations:

1. The video trials were conducted in a laboratory setting posing several limitations:
    a. Skateboarders may have felt less comfortable performing in a closed in atmosphere, absent of normal street wear clothing, fellow skateboarders, and the outdoors.
    b. The execution of the kickflip maneuver had to be performed on the limited size of the force platform, leading to added pressure of successful completion and strictness to the orientation and flare of the individual.

2. Participants were recruited from a sample of convenience rather than a random sample, and this sample may have performed differently than a random sample.

Delimitations

This study was subject to the following delimitations:

1. Participants must have been able to perform a kickflip from a rolling position onto the force platform not just a stationary, standing kickflip as is sometimes performed.
2. Participants must have had at least two years of experience to participate.
3. Participants must have been in good health, with no current or history of injury that may affect performance.

Assumptions

This study was subject to the following assumptions:

1. Participants will have knowledge of technique to perform the skill successfully
2. Participants will perform to the best of their ability or full potential according to the provisions of the study.

Operational Definitions

Angular Velocity – describes the speed of rotation and the orientation of the instantaneous axis about which the rotation occurs

Biomechanics – Mechanics that seeks to understand and explain human movement (Adrian & Cooper, 1995.)

Goofy foot – When the skateboarder leads with the left foot forward instead of the right

Ground Reaction Force – GRF - The reaction force as a result of applying a force to the ground.

Jerky Pattern – Where the order of peak velocities of adjacent segments occurs from distal to proximal (Smith & Wilkerson, 1997.)

Kickflip - Popping (putting pressure with your back foot) the tail of the deck and sliding the leading foot up to the top of the deck, bringing both board and rider off the ground. The front foot flicks it off the corner of the nose of the skateboard to create a flip. Feet are kept in the air allowing the board to spin and then lower feet and catch the board with feet after it has completed one full rotation.

Nose – the front end of the skateboard.

Ollie – As a skateboarder jumps up, and is about to take off, he/she kicks the tail of the board down, while rapidly picking their back foot back up quickly. The kick gives the front end of the board upward momentum, and as the tail hits the ground, it rebounds making the board completely airborne. When the board takes off, its nose is much higher off the ground than is the tail. The skateboarder slides his or her front foot up and forward on the griptape. The movement between the shoe and the board levels the skateboard and takes it further off the ground. Then as the skater descends, he/she lands on the bolts, preferably, and then bend their knees to absorb the impact.

Range of Motion – ROM- The range through which a joint can be moved; i.e. -thigh, trunk.

Regular foot – When the skateboarder leads with the right foot.

Shared Positive Contribution – SPC- referring to timing of the body segments in motion; that is there was neither an overlap nor a gap between the contributions of the joints.

Sequential Pattern – Timing of peak velocities of adjacent segments is arranged from proximal to distal, not all at once.

Simultaneous Pattern – When the peak velocities of adjacent segments occurs simultaneously.

Tail – the backend of the board

Take-Off –The point in time where the skateboarder left contact of the board in air while performing the kickflip; occurs before the flick stage of the maneuver.

Trucks – the metal mounted part of the skateboard on which the wheels are attached.

Velocity – The rate of position change over time.

Z direction – An infinite line approximately running vertically, as it refers to the force applied in this direction.

Null Hypotheses

The following null hypotheses were developed for this study:

1. There will be no significant differences in the maximal vertical ground reaction forces between groups of varying experience levels.
2. There will be no significant differences in the ROM of the hip, knee and ankle between groups of varying experience levels.
3. There will be no significant difference in the angles at take-off of the hip, knee and ankle between groups of varying experience levels.
4. There will be no significant differences in the shared positive contribution of the intersegmental coordination based on the timing of the angular velocities of the hip to knee, and knee to ankle between groups of varying experience levels.

CHAPTER 2

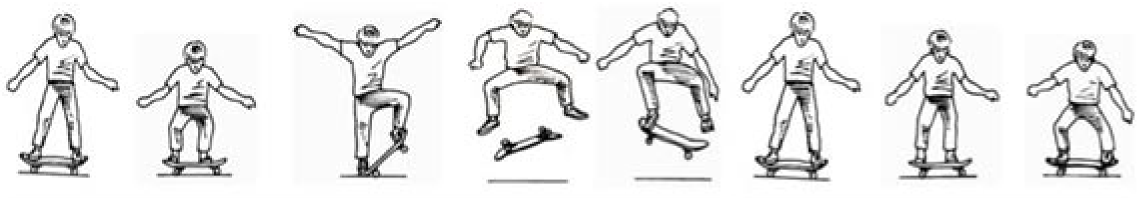
Review of Literature

This study will give a kinematic and ground reaction force assessment of two different levels of experienced skateboarders performing the kickflip maneuver. This will be achieved through an analysis of various kinematics of the skateboarder, take-off ground reaction force analysis and the description of the technique used to achieve the kickflip among the performance groups. The intent of this literature is to provide a foundation of previous research and expert opinions on topics associated with the kickflip. The first section details the kickflip technique. The second section describes studies done on the kickflip and other skateboarding studies. The third details the importance of timing of the body, or strategy, of the musculoskeletal system. This section will also include information regarding vertical jump performance. The fourth section describes shared positive contribution which provides information on the coordination of the body segments done while performing. The fifth section will describe the importance and relevance of the vertical jump in accomplishing the goal of the kickflip. The sixth section will summarize the importance of these sections to be covered. These sections should provide the reader with an understanding of the subject matter that will be investigated in the current study.

The Kickflip Technique

There is a consensus among websites (About.com, Rodneymullen.net, Ehow.com) of instruction that a kickflip maneuver has about 7 to 8 steps in order for successful completion. These steps are the stance, the pop, the flick, get out of the way, stay level, catch the board, land and roll away. The stance deals with foot placement on the skateboard. The back foot should be flat across the tail of skateboard, and the ball of the front foot should be right behind the front trucks. The pop is the beginning action of the movement. This is where the skateboarder slams the back foot down on the tail of the skateboard as hard as possible. At that moment, the skateboarder wants to also jump into the air, off of their back foot. This ability is necessary, and takes practice; the trick is in getting the timing right. The skateboarder will want to slap the skateboard's tail down, and as it hits the ground, the skateboarder should jump off of that foot into the air. It is a quick, snapping motion. The flick is where the foot should slide up toward the edge of the nose of the board and flick the nose of the skateboard with the front foot. Then the skateboarder should kick the foot out toward the heel side of the skateboard, using the top of toes to flick the board. The motion of the foot should be out, and a little down. The target is the corner of the nose of the skateboard. The flick should be done on the skateboard because that is where the skateboarder will have the most control. After flicking the board with the front foot, getting the feet out of the way is next so that the board can flip in the air. This step is important. After flicking the skateboard, the skateboarder must pull their front foot out and up. This is all happening in the air, and very quickly. While the skateboard is flipping underneath the skateboarder, it can be easy to lose a level stature. Keeping shoulders level with the ground and pointed in the direction of travel is important. Staying level will aid in a successful landing. Catching the board is next. Once the skateboard has spun around completely one time, the skateboarder must place the back foot on it to catch it. Watching the skateboard, to see when it has made one complete flip, is necessary to accomplish this goal. Once the catch of the skateboard is made with the back foot, the front foot should then be placed on the skateboard too. Next, as the skateboarder falls back toward the ground to land, knees should be bent again to help absorb the shock of landing. Finally, the skateboarder should be able to roll away.

Figure 1. The Kickflip



Studies on the Kickflip and Skateboarding

Despite the global popularity of skateboarding, little is known about the biomechanics of the sport. In this study, the aim is to partially rectify this paucity of hard data by describing the kinematics and ground reaction forces of a common movement used by intermediate and advanced skateboarders: the kickflip. A kickflip is a jumping maneuver used by skateboarders to hop onto, off of, and over obstacles.

A kickflip is similar in motion to an Ollie but differs slightly as it incorporates a kicking or flicking motion of the foot during the airborne phase of the jump that causes the board to rotate in the air about its long axis underneath the skater’s feet (Determan, Fredrick, Cox & Nevitt, 2006).   The study conducted by Determan et al. in the afore mentioned, found of the kickflip that an example vertical ground reaction force (VGRF) force-time curve typically rose slightly above one bodyweight (BW) during the first 200 ms of the movement as the subject initially plantar flexed their ankles on the skateboard before rapidly lowering their center of mass by flexing their ankles, knees, and hips. The VGRF then rose rapidly as the subjects jumped into the air off their back foot while their front foot controlled the motion and direction of their skateboard. The aim was to partially rectify this paucity of hard data by describing the kinetics of a common movement used by intermediate and advanced skateboarders termed the kickflip.

The magnitudes of the VGRF during take-off and landing were similar to previous studies by Frederick et al. who studied skateboarders performing Ollies up onto and off of a 45.7 cm wooden platform. In this study, forces were found to be 2.22 BW's when their subjects first rolled onto a force plate and allied up onto the platform.

Another study by Determan et al. (2006b) determined VGRF among 7 professional skateboarders performing the kickflip maneuver. The first VGRF peak, occurring after both wheels were on the force plate is usually lower in magnitude than the second. A force minimum is reached in between the two peaks. This appears to be the result of an un-weighting of the board as the center of mass is lowered just prior to the jump. The second and higher magnitude peak is the result of the force applied to cause the board and skater to leave the ground. These peak values are similar in magnitude to those observed in runners who raise the center of mass to a much lesser extent in each step (Frederick, Hagy, 1986). Findings in this study will be compared and contrasted to those found by Fredrick, et al. 2006.

Timing of the Body Segments: Strategy

Timing of the body segments is considered to be an important factor for producing maximum velocity at the distal end of a segment (Phillips, 1978; Youm Huang, Zernicke, & Roberts, 1973; Zernicke & Roberts, 1976, 1978). Looking at the skateboarder's movement for action at the knee and ankle to produce a kickflip will be telling of technique to accomplish this goal.

Mathiyakom, McNitt-Gray and Wilcox (2002), determined that identification of control strategies implemented during impulse generation under diverse conditions reveals how constraints imposed by task objectives influences motor behavior and distribution of mechanical load within the musculoskeletal system. Impulse applied to the ground is result of coordinated activation of muscles that accelerate and perform mechanical work on the segments. For example, during tasks requiring the generation of vertical impulse (e.g. maximum vertical jump or take-off), orientation of the segments during impulse generation influences the proportion of segment energy contributing to the task objective (Bobbert & van Ingen Schenau, 1988). Therefore, determining skateboarder's kinematics, and in particular, segmental angular velocities will provide information regarding technique of movement.

One study examined maximal vertical jumping and whether it can be performed by the use of either sequential or a simultaneous dynamic strategy (Ravn, Voight, Simonsen, Alkjae, Bojsen-Moller, & Klansen, 1999). It is likely that some methods of vertical jumps may impose constraints of an external and/or anatomical nature, which could imply the requirements of either a sequential or simultaneous strategy. In contrast, during a maximal vertical jump starting with a countermovement jump (CMJ), it seems likely that the use of different strategies is solely dependent on the subject's choice. For skilled experienced skateboarders, the choice of strategy could be either the result of training for a specific jumping event or an inherited preference for a particular strategy.

It is important to also look at the values provide by other studies of the forces produced by the vertical jump. These values can then be related to those of the vertical jump take-off values off of the skateboard.

The peak VGRF values in the present study are greater than in previous studies. This could be due to the differences in athletic ability of the subjects since previous studies used collegiate volleyball players (Horita, T., Kitamra, K., Kohno, N., 1991) and students studying physical education (Aguado, X., Izquierdo, M., Montesinos, J.L., 1997 & Izquierdo, M., Auguado, X., Ribas, T., Linares, F., Vila, L., Voces, J.A., Alvarez, A.I., Prieto, J.G., 1998). Although it might not be viewed that skateboarders are trained athletes, the subjects in this study skateboard everyday and for long hours. Another reason for higher peak VGRF values could be the force generated off of the skateboard. The mean peak VGRF values of the current study are about 1 BW higher than that of previous vertical jumping studies (2.7 BW for the novice and 3.4 BW for the experienced). Previous vertical jump studies have values of 2.3, 2.3, 2.1 and 2.3 BW (Ashby, B. & Heegaard, J., 2002).

Shared positive contribution

Bird, Hills and Hudson (1991) developed a way of calculation to describe the movement of intersegmental coordination. They examined beginner and advanced performers in a two-segment, lever like task, and the badminton deep serve. The participants had to place the shuttlecock in the rear section of the opponent’s court with sufficient accuracy and velocity to enable the shuttlecock to travel high as well as far. Shoulder angular velocities and wrist angular velocities were calculated to determine a pattern of coordination. The defined the propulsive phase for each segment as beginning when the joint velocity crossed a zero velocity and ending when the joint velocity reached maximum.

Intersegmental coordination in complex, forceful movements has been discussed in the biomechanics nomenclature for many years. The presumption has been that the optimal pattern of coordination was sequentially timed (Morehouse & Cooper, 1950; Bunn, 1972). The sequencing of segments was ordered from proximal to distal, and the timing of segments was arranged such that exactly one segment contributed positively to the movement at a given time. Alterations from optimal timing were described by Morehouse and Cooper in continuous terms ranging from "early" (i.e., overlaps in segmental contribution) to "late" (i.e., gaps in segmental contribution). Similarly, Bunn advised against "simultaneous" or "jerky" movements.

In 1981, Kreighbaum and Barthels suggested a different timing continuum with polar positions of simultaneous (i.e., all segments contribute concurrently) and sequential (i.e., each segment contributes serially). They also predicted that the position on the continuum for a particular performer and task would be related to other factors involved in the movement. For example, if the performer were a beginner or the task involved limited incorporation of segments, lever-like movement, or accuracy, the expected mode of timing would be simultaneous. If the performer was advanced and the task involved maximal incorporation of segments, wheel-axle movement, or velocity, the expected mode of timing would be sequential. Given the complexity of sports skills in terms of these contextual factors, it is not surprising that there are few empirical studies of context and coordination.

To date, skateboarding has not been analyzed in terms of intersegmental coordination. Jumping (Bobbert & van Ingen Schenau, 1988; Hudson, 1986) and speed skating (Koning,

1991) are among those studied in terms of intersegmental coordination. From the data depicted in these studies, it appears that the thigh and shank operate with predominant simultaneity in both these tasks. That is, the thigh and shank both begin and end their propulsive phases at approximately the same times. Using these similar tasks one wonders if skateboarding can relate.

Vertical Jumping Significance to the Kickflip

Vertical jumping is regarded as an important and attractive element of many sports such as basketball and volleyball. Papers are regularly published in exercise science publications, both lay and scientific, about training methods for vertical jump performance improvement (Adams, 1984; Bobbert & Van Soest, 1994; Brown, Mayhew, & Boleach, 1986; Kraemer & Newton, 1994; Wilson, Newton, Murphy, & Humphries, 1993). A key step in performing the kickflip begins with the vertical jump off of the skateboard. The shared positive contribution that will be examined in this study will provide information if indeed the kickflip is a simultaneous movement relevant to that of the vertical jump. This will allow information that has been studied by numerous researchers of the vertical jump to be applied to that of skateboarding.

Summary

The importance of studying the VGRF, lower body kinematics and SPC is to see if there is a technique that is optimal in accomplishing the kickflip. By examining the force used to accomplish this goal among the two groups, a possible preferable force production can be determined. This data can provide information on reducing injury and creating equipment necessary to cushion forces received on the body. Looking at body kinematics and the contribution of those segments SPC, will also hope to provide some data in optimal technique of the movement and if it is similar to the vertical jump which may allow for information to be shared with skateboarders for possible training exercises to improve movement.

CHAPTER 3

Methods

The purpose of this study was to examine vertical ground reaction forces (VGRF) and body kinematics of a kickflip maneuver to compare the technique of novice and experienced skateboarders. Examination of the vertical ground reaction force at take-off for a skateboarder to perform the desired maneuver is critical in providing data that indicates impact on the body. This data can be used to reduce injury, enhance performance and increase the longevity of the skateboarder. Studying the kinematics will provide us with a possible pattern of movement of the body segments to describe technique.

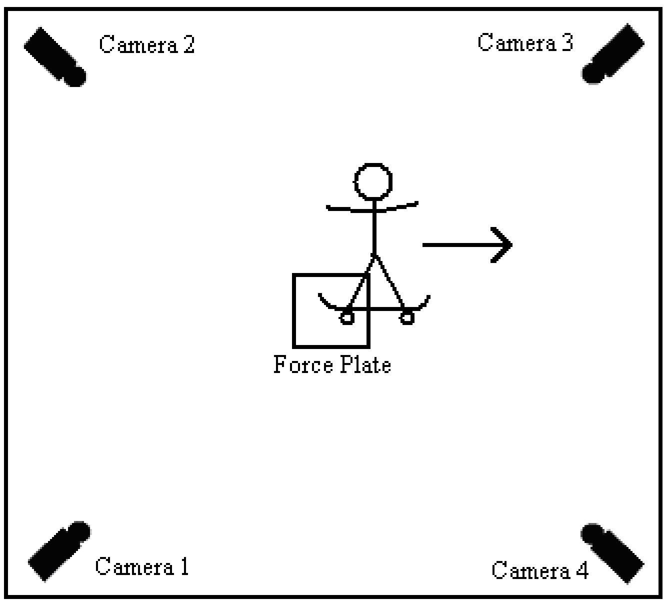
Participants

Participants consisted of six (6) male skateboarders with at least two years of skateboarding experience and varying levels of accomplishment of the performance of the kickflip. The two groups were separated in novice v. experienced based on the number of successful landings of the kickflip conducted in the pretest of best of eleven attempts. Those skateboarders who landed five (5) or less out of eleven (11) attempts of the kickflip were placed in the novice group. Those skateboarders who landed six (6) or more out of eleven (11) kickflips were placed in the experienced group. The two groups consisted of three (3) skateboarders each. All participants were recruited from local skateboarding shops in close proximity to Barry University. All participants were asked to read and sign an informed consent form detailing the study's procedures, as well as any risks and consequences of the study.

Instruments

The study incorporated the use of four JVC 60 Hz video cameras. The cameras were placed in the four corners of the laboratory, a facility with an approximate size of 8 x 14 ft.

Figure 2. Camera Set-up in the Biomechanics Lab



They were placed at an approximate height of 1.5 m. A calibration module with an approximate size of 2 x 2 x 2 m and containing 21 balls with known coordinates was used to calibrate the cameras. The module and all of the kickflip maneuvers were videotaped, and the images on the tapes were transferred into a computer, then later digitized and analyzed using Vicon Peak Motus Ver. 8.2 (Vicon Peak Perform Tech, Inc., Centennial, CO) motion analysis software. A multi-component force plate (AMTI 4507) was used. Ground reaction forces were recorded directly into the computer program through an A/D converter. The ground reaction forces were amplified (SGA6-4) with a gain set at 4000 Hz. Kinematic and reaction force data were synchronized at the time of initial contact with the force plate. The skateboarders performed a kickflip on top of the force platform. All participants used the same skateboard. The skateboard deck used was a Hopps Deck, 31.5 inches X 7.6 inches. 7/8 Allen hardware was used with Bones Red bearings, Habitat 52mm wheels and Independent 129 trucks. The skateboard weighed 5 lbs.

Procedures

Each participant reported to the biomechanics laboratory for testing at a previously assigned time. After reading and signing the informed consent form, the skateboarders were asked to change into snug fitting dark colored and sleeveless tees and/or remain shirtless. A helmet, elbow pads and knee pads were provided and used by the skateboarders for safety. Before data was recorded, all participants were given time to familiarize themselves with the laboratory setting and be given a full description of precisely what would be asked of them for their trials. The skateboarders went over the force place for timing to be able to perform with both back wheels on the force plate at the time of take-off.

Reflective markers were attached with an adhesive sticker with reflective marker attached laterally on the side of body that had the corresponding foot on the back of the board at take-off on the shoulder, the greater trochanter (hip), the lateral femoral condyle (knee), and on the lateral malleolus (ankle). After the markers were placed on the participant, any additional time needed to adjust to performing while wearing them was given.

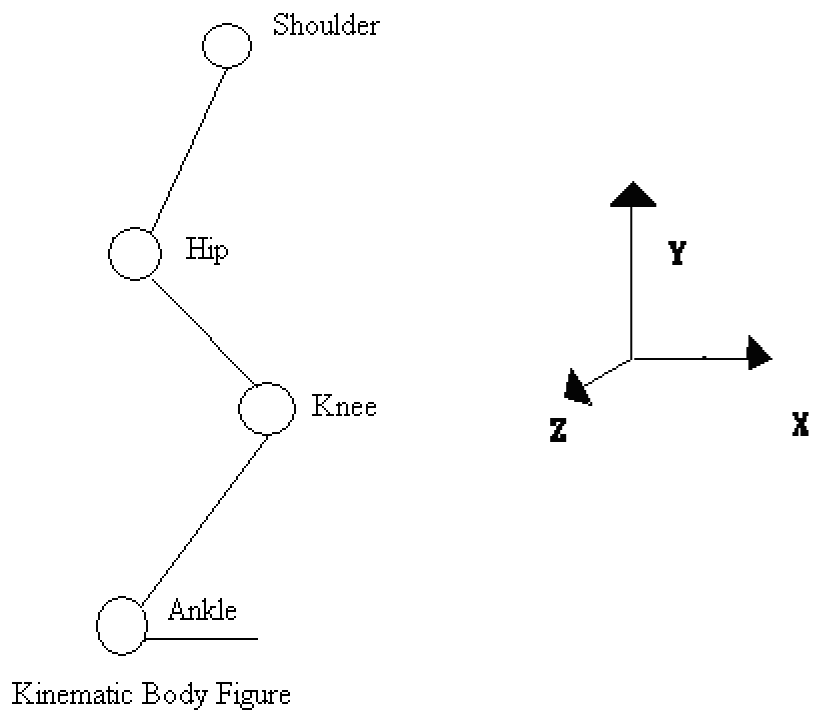
No instruction was given on how to complete the kickflip. The subjects were allowed to perform the maneuver in two acceptable trials, based on what the participant felt was most natural, and were videotaped and analyzed. No other instruction or restrictions were given.

Design and Analysis

After the entire session for a skateboarder was videotaped, the footage was cropped to include only data needed from the contact of the board with the force plate needed for synching purposes through the tenth frame after subject was fully airborne. All points for which the reflective markers were used were digitized automatically.

Individual differences occur among skateboarders that usually result in unique body orientations in which to accomplish their goal, this also called technique. The independent variable is the skill level of the skateboarder, experience and novice. The dependent variables were the range of motion (ROM) of the hip, knee and ankle from maximum flexion to take-off. Angular velocities of the hip, knee and ankle at take-off were also calculated. And the SPC between the hip and knee, and knee and ankle were also reported. (See figure 3 below).

Figure 3. Kinematic Body Figure



The knee angle was calculated as a vector angle between the greater trochanter, the knee and the malleolus.

Shared positive contribution (SPC) was calculated between each of the fore mentioned angle and segment among the amateurs and the experienced skateboarders. SPC was computed by dividing the time that both segments were in simultaneous propulsion (velocities are positive and increasing) by the time that either segment is in propulsion (Bird, Hill, & Hudson, 1991). There is a difference between SPC of proximal to distal initiation and SPC of distal to proximal initiation (Smith & Wilkerson, 1997). The SPC of distal to proximal initiation were subtracted from 200 and expressed as a value between 100 and 200. For example, an SPC of 50% (proximal to distal) is recorded as 50% whereas an SPC of 50% (distal to proximal) is recorded as 150%. Any value over 100% indicates a distal to proximal initiation and a characteristically an immature pattern of coordination. The following classifications were used assessing the overall coordination of the skill: (a) sequential pattern, 0%-33% SPC; (b) intermediate pattern, 34%-66% SPC; (c) simultaneous pattern, 67% - 100% SPC; and (d) jerky pattern (distal-proximal) 101%-200 SPC (Smith & Wilkerson, 1997).

Data Analysis

A Hotelling's T ($p<.05$) was used to analyze the data for the hypotheses of no significant differences between novice and experienced skateboarders for (a) the take-off angle at the hip, knee and ankle (b) range of motion of the hip, knee and ankle from maximum flexion to take-off (c) the shared positive contribution of the hip to knee and the knee to ankle segments. An independent samples t-test ($p<.05$) was used to determine the differences in VGRFs of the two groups of skateboarders. Statistical data was calculated through the SPSS version 14.0 for Windows program to present descriptives for the data sets and graphs.

CHAPTER 4

Results

The purpose of this investigation was to determine if differences in selected parameters of skateboarding technique exist between skateboarders with varying levels of experience. Variables of interest were the maximum values of VGRF, take-off angles of the hip, knee and ankle, range of motion of the hip, knee and ankle and the shared positive contribution of the hip to knee and knee to ankle to accomplish the successful landing of a kickflip. No previous studies have scientifically analyzed this common maneuver in skateboarding. These variables will hopefully project some data that may show significant differences between the two groups which could shed light on the technique of accomplishing a successful kickflip. The findings of this investigation are organized under the following headings (a) Description of the Participants, (b) Analysis of the Movement Data, (c) Statistical Analysis of Data, (d) Examination of the Hypotheses, and (e) Summary of the Hypotheses.

Description of the Participants

Participants consisted of six (6) male skateboarders with at least two years of skateboarding experience and varying levels of accomplishment of the performance of the kickflip. The two groups were separated in novice v. experienced based on the number of successful landings of the kickflip conducted in the pretest of best of eleven attempts. Those skateboarders who landed five (5) or less out of eleven (11) attempts of the kickflip were placed in the novice group. Those skateboarders who landed six (6) or more out of eleven (11) kickflips were placed in the experienced group. The two groups consisted of three (3) skateboarders each. Demographic data including age, weight, height, years of experience in skateboarding, years of experience attempting the kickflip, regular or goofy foot techniques, and dominant foot data were collected from each participant. Demographic data for each group are presented in Table 1.

Table 1.

Demographic Data of the Participants

Variable	Novice		Experienced	
	Mean	SD	Mean	SD
Age (yrs)	28.3	.9	26.6	3.5
Weight (kg)	73.1	2.8	65.5	3.9
Height (cm)	185.1	1.1	169.3	1.7
Years of Experience	15.7	2.0	14.3	2.9
Years of Kickflip Experience	8.5	1.6	12.7	2.2

*All subjects were regular footed
*All subjects were right foot dominant

As can be seen by viewing Table 1 mean age, mean weight, and mean height were all relatively close among the groups. A main focus and point of interest of the demographic data is that of the years of experience in skateboarding and that of the years of experience in being able to perform the kickflip. Overall, the group with more years of skateboarding experience had less years of kickflip experience, the novice group. In contrast, the group with less years of skateboarding experience had more years of kickflip experience, the experienced group.

Analysis of Movement Data

Take-off in this study is defined as the point in time where the skateboarder left contact of the board in air while performing the kickflip. This take-off point occurs after maximum VGRF has been reached. See figures below.

Figure 4. Approach - Novice

Figure 5. Take-off - Novice

As seen in Figure 5, the novice kickflipper has his wheels off the force plate only and inch or two and foot contact with the board occurs very close to the board while limbs are relatively straight.

Figure 6. Approach - Experienced

Figure 7. Take-off - Experienced

Figure 7, provides a visual that shows the experienced kickflipper has popped his board more than the novice, which indicates more force produced, and therefore is in the air about 6 inches off the ground before he begins his flick of the board. His limbs have grater flexion and range of motion than the novice.

The mean maximum VGRF was greater from the experienced group v. the novice group (2211.09 N v. 1949.609 N, 3.4 BW v. 2.7 BW) (See Table 2).

Table 2. Maximum Vertical Ground Reaction Forces (VGRF in Newtons, N) and (Body Weights, BW) and Means

Novice		**Experienced**	
Subject 2	1791.96 N, 2.4 BW	*Subject 1*	2147.09 N, 3.3 BW
Subject 5	2396.55 N, 3.6 BW	*Subject 3*	1820.57 N, 3.2 BW
Subject 6	1660.32 N, 2.2 BW	*Subject 4*	2665.61 N, 3.8 BW
Mean	**1949.61 N (2.7 BW), SD 392.62 N**	**Mean**	**2211.09 N (3.4 BW), SD 426.14 N**

The mean ROM of as depicted in the pictures of Figure 4 to 5 and Figure 6 to 7 is greater in the experienced v. novice. See Table 3 below and Figures 4, 5, 6 and 7 above. The mean range of motion of the novice group was less than the range of motion of the experienced group in the hip, knee and ankle. The mean ROM for the hip was 34.6° for novice and 75.6° for the experienced group. The experienced group had on average a 41.0° greater hip ROM than the novice group. The range of motion at the knee was 39.8° and 81.7° for the mean of the novice and experienced group respectively. The experienced group had a 41.8° average greater ROM at the knee than the novice group. And, the mean range of motion at the ankle was 33.6° for the novice group and 48.7° for the experienced group. The experienced group had a 15.2° greater ROM on average at the ankle than the novice group.

Table 3. Range of Motion of Joint Angles (Degrees º)

Novice		Experienced	
Subject 2		**Subject 1**	
Hip	57.7	Hip	89.9
Knee	68.2	Knee	75.9
Ankle	50.2	Ankle	41.2
Subject 5		**Subject 3**	
Hip	5.9	Hip	53.7
Knee	15.6	Knee	79.5
Ankle	2.2	Ankle	60.9
Subject 6		**Subject 4**	
Hip	40.1	Hip	82.9
Knee	35.8	Knee	89.5
Ankle	48.2	Ankle	44.1
Hip	Mean 34.6 SD 26.3	Hip	Mean 75.6 SD 19.2
Knee	Mean 39.8 SD 26.5	Knee	Mean 81.7 SD 7.0
Ankle	Mean 33.6 SD 27.2	Ankle	Mean 48.7 SD 10.6

The take-off angles of the hip, knee and ankle provide data of the position of the body while in air before the flick stage of the maneuver (See Table 4).

Table 4. Take-off Angles of the Hip, Knee and Ankle (Degrees°)

Novice		Experienced	
Subject 2		**Subject 1**	
Hip	157.3	Hip	152.8
Knee	161.3	Knee	140.9
Ankle	115.3	Ankle	98.4
Subject 5		**Subject 3**	
Hip	99.3	Hip	135.6
Knee	76.5	Knee	143.3
Ankle	77.1	Ankle	120.7
Subject 6		**Subject 4**	
Hip	117.4	Hip	141.1
Knee	125.4	Knee	134.9
Ankle	73.3	Ankle	105.2
Hip	Mean 124.7 SD 17.1	Hip	Mean 143.2 SD 5.0
Knee	Mean 121.1 SD 24.6	Knee	Mean 139.7 SD 2.5
Ankle	Mean 88.6 SD 13.4	Ankle	Mean 108.1 SD 6.6

At take-off, the point where the skateboarder left contact with the board while in air before the flick stage of the maneuver, on average the experienced group had greater joint ankles than the novice group at the hip, knee and ankle. The mean angle at the hip was 124.6° for the novice group and 143.2° for the experienced group. The experienced group had an 18.5° average greater angle than the novice group at the hip. The mean angle at the knee was 121.1° for the novice group and 139.7° for the experienced group. The experienced group had an 18.7° average greater angle than the novice group at the knee. The mean angle at the ankle was 88.5° for the novice group and 108.1° for the experienced group. The experienced group had a 19.6° average greater angle than the novice group at the ankle.

The SPC of *novice* skateboarders is intermediate in pattern as it is simultaneous with segments contributing differently from subject to subject. The SPC of *experienced* skateboarders is all simultaneous in pattern with the one exception of one skateboarder in knee to ankle pattern. See Table 5.

Table 5. Shared Positive Contribution (%) and classification pattern

Novice		
	%	Classification Pattern
Subject 2		
Hip to Knee	65%	intermediate
Knee to Ankle	100%	simultaneous
Subject 5		
Hip to Knee	89%	simultaneous
Knee to Ankle	57%	intermediate
Subject 6		
Hip to Knee	80%	simultaneous
Knee to Ankle	50%	intermediate
Experienced		
	%	Classification
Subject 1		
Hip to Knee	68%	simultaneous
Knee to Ankle	54%	intermediate
Subject 3		
Hip to Knee	87%	simultaneous
Knee to Ankle	79%	simultaneous
Subject 4		
Hip to Knee	83%	simultaneous
Knee to Ankle	83%	simultaneous

As seen in Table 5, the SPC for Subject 2 had an intermediate pattern classification from the hip to knee and a simultaneous pattern classification from the knee to ankle. Subject 5 had a simultaneous pattern classification from the hip to knee and an intermediate pattern classification from the knee to ankle. Subject 6 had a simultaneous pattern classification from the hip to knee and an intermediate pattern classification from the knee to ankle. These participants were all in the novice group. For the experienced group, all movement was considered simultaneous in pattern with the exception of knee to ankle in Subject 1.

Figures 8 and 9 depict an example of the angular velocity of the hip knee and ankle joints of the novice and the experienced skateboarder. By observing the overlap and the point at which the peaks of each joint reach their maximum velocity it can be determined how much each joint angle contributes positively throughout the movement. By observing when the peaks occur in time it can be determined if the movement is sequential (peaks reached at different times) or simultaneous (peaks reached at relatively the same time) (See Figures 8 & 9). Figure 8 has arcs reaching their peak at different times representing a mostly sequential movement. Figure 9 has arcs that reach their peaks at relatively the same time representing a mostly sequential movement.

Figure 8.

Novice

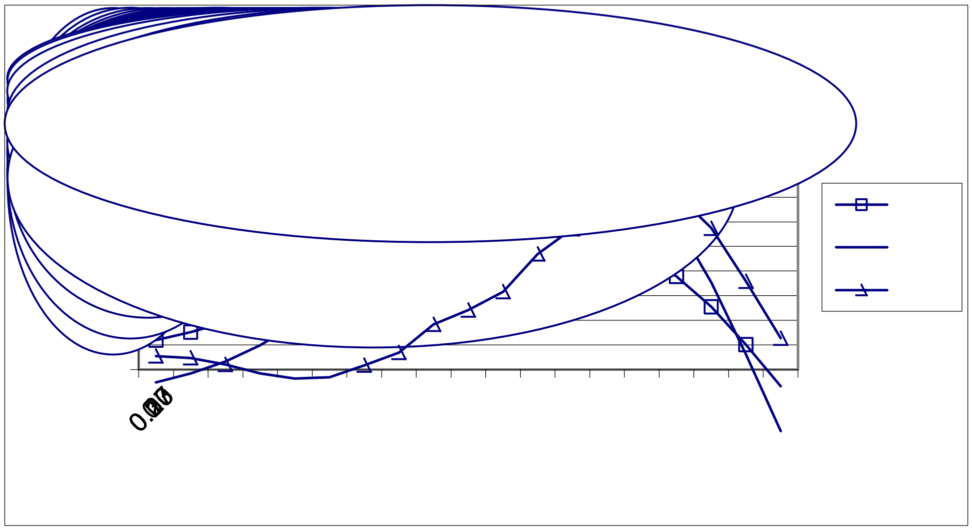
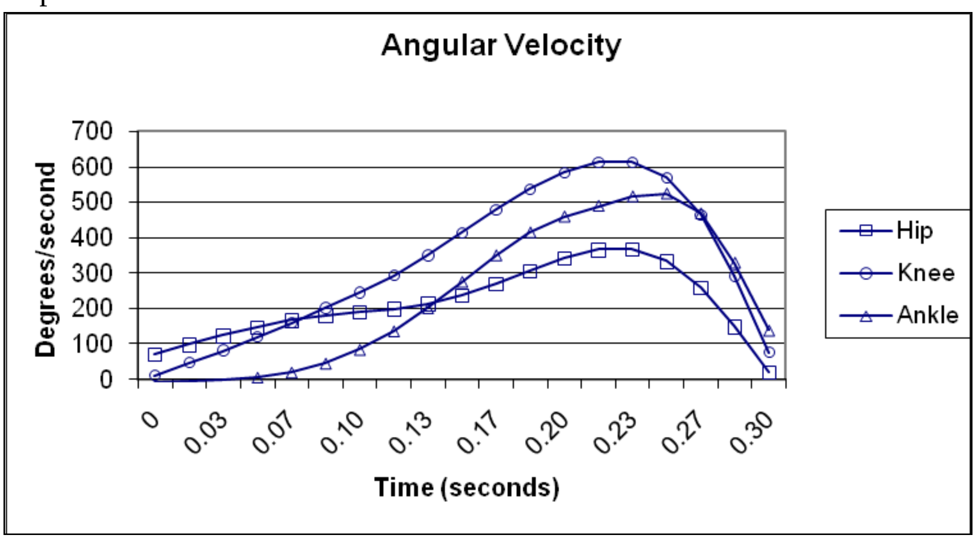


Figure 9.

Experienced



The Force-Time Curve graphs depict entire movement recorded from weight acceptance of the board to take-off of the kickflip (See Figures 10 and 11 of the subjects' force-time curve of their VGRF and Hip, Knee and Ankle Graphs.).

Figure 10. Force – Time Curve

Novice Group. Subject 5.

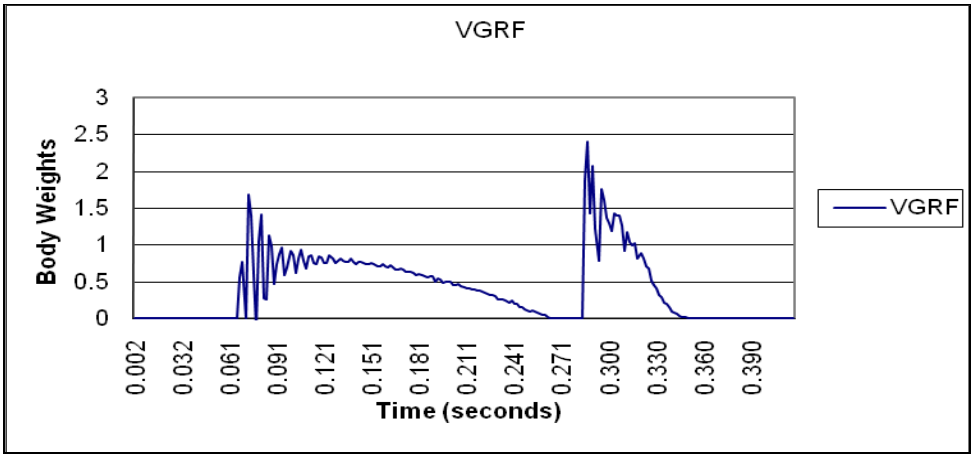
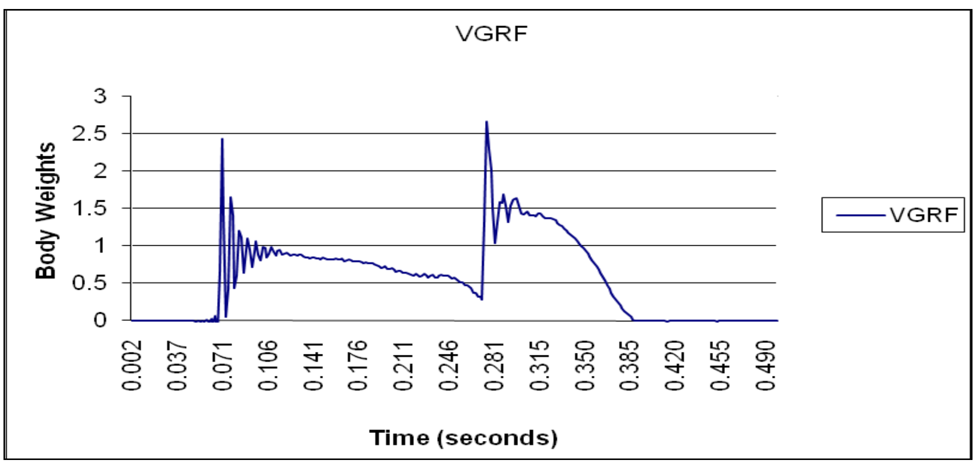


Figure 11. Force -- Time Curve

Experienced Group. Subject 1.



The first VGRF peak, occurring after both wheels are on the force plate, is usually lower in magnitude than the second peak. This is followed by a force minimum, or at least a cessation of the rise in force, that is reached in between the two peaks. This appears to be a result of the unweighing of the board as the center of mass is lowered prior to the kickflip jump. These graphs coincide with findings of Fredrick et. al (2006) and Determan et. al (2006b) in their studies done on the Ollie and the Kickflip where they also depicted graphs of the two peak VGRF. The second and usually higher magnitude peak is the result of force applied rapidly by the back foot to the tail of the board as it is rotated about the rear axel and slammed into the ground. The magnitude of these second propulsive peaks has a mean of 1949.609 N ±393.62 N for the novice group and 2211.09 N ±426.14 N for the experienced group. Typically the VGRF rose slightly above one bodyweight (BW) during the first 200-300 ms of the movement as the subject initially dorsi flexed their ankles on the skateboard before rapidly lowering their center of mass by flexing their ankles, knees, and hips. The VGRF then rose rapidly as the subjects jumped into the air off their back foot while their front foot controlled the motion and direction of the skateboard. This VGRF, the second hump, rose to around 3 or more times bodyweight.

Statistical Analysis of Data

An independent samples *t* test was calculated comparing the mean value of max VGRFs between groups novice v. experienced skateboarders. No significant difference was found ($t(1) = .478$, $p > .05$). The mean of the novice group (1) is 1949.61 N ±392.6. The mean of the experienced group (2) was 2211.09 N ±426.1.

A one way MANOVA was calculated examining the ROM of the hip, knee and ankle between groups. No significant effect was found (Hotelling's T (3,2) = .422 $p > .05$).

A one way MANOVA was calculated examining the take-off angles of the hip, knee and ankle between groups. No significant effect was found (Hotelling's T (3,2) =.377 $p > .05$).

A one way MANOVA was calculated examining the SPC of the hip to knee and the knee to ankle between groups. No significant effect was found (Hotelling's T (3,2) = .975 $p > .05$).

Examination of the Hypotheses

The first hypothesis stated there will be no significant differences in the maximal vertical ground reaction forces between groups of varying experience levels. This hypothesis was accepted. However, a qualitative analysis was done to discuss some findings of the differences between the groups, although not statistically significant.

The second hypothesis stated there will be no significant differences in the ROM of the hip, knee and ankle between groups of varying experience levels. This hypothesis was accepted. However, a qualitative analysis was done to discuss some findings of the differences between the groups, although not statistically significant.

The third hypothesis stated there will be no significant difference in the angles at take-off of the hip, knee and ankle between groups of varying experience levels. This hypothesis was accepted. However, a qualitative analysis was done to discuss some findings of the differences between the groups, although not statistically significant.

The fourth hypothesis stated there will be no significant differences in the shared positive contribution of the intersegmental coordination based on the timing of the angular velocities of the hip to knee, and knee to ankle between groups of varying experience levels. This hypothesis was accepted. However, a qualitative analysis was done to discuss some findings of the differences between the groups, although not statistically significant.

Summary of the Hypotheses

The following hypotheses were examined at the .05 level of significance:

1. There will be no significant differences in the maximal vertical ground reaction forces between groups of varying experience levels.

ACCEPTED

2. There will be no significant differences in the ROM of the hip, knee and ankle between groups of varying experience levels.

ACCEPTED

3. There will be no significant difference in the angles at take-off of the hip, knee and ankle between groups of varying experience levels.

ACCEPTED

4. There will be no significant differences in the shared positive contribution of the intersegmental coordination based on the timing of the angular velocities of the hip to knee, and knee to ankle between groups of varying experience levels.

ACCEPTED

CHAPTER 5

Discussion

One common maneuver in skateboarding is the kickflip. It is considered to be the most difficult of the easier maneuvers of the sport. Studies to date have not detailed the lower body kinematics and movement production used to accomplish the task of a kickflip. Forces have been analyzed but the technique of the movement has not been quantified until now, in this current study. It is hoped that this study would be of benefit to the scientific community as well as the skateboarders who wish to learn how to accomplish the goal of a kickflip. By studying the technique of the movement training implications were also found to help improve the accomplishment of the kickflip. This movement proved to be simultaneous in the experienced group of skateboarders and can be related to the vertical jump and its implications for training and optimal accomplishment.

Vertical Jump Relevance

The coordination of a maximal vertical jump from stance is very similar among individuals. This stereotyped execution of maximal vertical jump is reported to be the result of optimizing neuromuscular control through which one optimal solution for maximal jump height is reached (Bobbert & van Ingen Schenau, 1988; Hatze, 1998.) The optimal solution typically shows a proximal to distal sequence of segmental motions (Bobbert & van Ingen Schenau, 1988) and as a consequence the subject is able to keep contact with the ground until the hip and knee joint are nearly extended (van Ingen Schenau, 1989).

Another property of the musculo-skeletal system that can influence movement effectiveness is the horizontal orientation of the foot segment, which as instructed by the consensus of literature for the kickflip is very important. This is advantageous as the ankle is partially flexed in the initial stance phase on the skateboard. The necessary flexion prior to the jump is less important and required less in the hip and knee joints than in the ankle. As seen in the experienced subjects their degree of ankle flexion and ROM was greater than those of the inexperienced and greater than the change between the hip and the knee. Most work is therefore done with preciseness at the ankle.

Theoretically, an infinite number of strategies are possible to perform a vertical jump. However, this study showed consistency among subjects, suggesting that a certain criterion drives jumping strategy into a consistent pattern. That pattern varies among the two groups of novice and experienced. Vertical jump training would be advantageous but coordination is different because of the skateboard.

Similar Findings to Previous Studies

Amplitudes and force time curves of this study's dataset were very similar to those reported in previous studies. The kinematics of the maximal jump condition, i.e. joint angular displacements showed good agreement with those found by Bobbert and van Ingen Schenau (1988). And the kinetics of the jump condition, i.e. force produced at take-off, showed good agreement with those found by Determan, (2006a+b) and Fredrick, (2006).

Another musculo-skeletal property related to movement effectiveness is the initial foot segment orientation. The initial dorsi-flexed position of the ankle joint has an advantage compared to the hip and knee joints, as less flexion, is required before the joint is able to extend. This is shown in the relatively small changes in ROM at the ankle but it is none the less a critical if not the most important factor in accomplishing the kickflip. The experienced group relied heavily on their greater ROM and ankle flexion than the novice group.

When analyzing the previous findings, yet another property of the musculo-skeletal system which could influence the control of jumping is the fact that distal muscles have shorter muscle fibers and longer tendons compared to the proximal muscles (Yamaguchi, Sawa, Moran, Fessler & Winters, 1990; Voigt, Simonsen, Dyhre-Poullsen, & Klausen, 1995.) Vertical jumps, as in the kickflip as found in this study, are mainly performed by extending actions of the distal ankle joints, and consequently stretch-shortening of the distal muscle-tendon complexes. Muscles go through a stretch phase and then a contraction phase. Plyometric exercises are designed to shorten the cycle time between the two phases. A rapid cycle time allows maximum energy transfer between stretch and contraction phases. This leads us to the importance of training and strengthening these ankle muscles as defined, studied and determined through many vertical jump training exercises would also help improve the performance of the kickflip.

Trends from Video Evidence

The main findings of this present study were not statistically significant and had low power. However, the four main areas of interest can be discussed with some relevance based on the differences found between the groups in the data. The magnitudes of the VGRF during takeoff and landing were similar to previous studies by Frederick et al. data who studied skateboarders performing ollies up onto and off of a 45.7 cm wooden platform. In their study, take-off forces were found to be 2.22 BW's when their subjects first rolled onto a force plate and ollied up onto the platform. In this current study take-off force produced was between 2.7 and 3.4 BW's. Further analysis of this current study's VGRF data also shows the magnitudes and shape of the force-time curve are similar to other studies examining countermovement vertical jumps. McClay et al. (1994), studied vertical jumps in professional basketball athletes and found average take-off forces to be 1.7 ± 0.52 BW's and forces to be 4.3 ± 1.16 BW's, though no jump heights are reported. Dowling and Vamos (1993) examined vertical jumps of 97 young adults and found take-off forces ranging from 1.8 to 2.8 BW's for jump heights similar to those recorded in this study (2.7-3.4 BW's). The fact that ollie and kickflip movements so closely mirror other jumping movement sports such as basketball and volleyball, at least on a kinetic level, suggests that skateboarders may benefit from similar training exercises used in these more traditional sports to increase jump height ability. If skateboarders could increase their jumping ability they could theoretically be able to jump over higher objects with their boards or increase the number of revolutions the board completes during kickflips.

The participants in this study are not representative of a cross section of North American skateboarders. In a recent survey of 797 North American skateboarders, it was found that the average skateboarder was younger (mean age of 15 years 8 mos.) and lower in body mass (mean of 56.7 kg) than the experienced and more mature skateboarders in this study (Determan, 2006b). Caution needs to be exercised when applying the data collected in this study to the general population. Nevertheless, the task asked of the skateboarders to perform was not extreme and within the level of many typical skateboarders. The data of this study is scaled to body mass and finding of force are relative to those of the general skateboarding population.

The forces found in this study also support the need of manufactures of equipment to provide necessary footwear to ensure proper functional properties and properties to prevent damage to the immaturity of the skeletal system in the typical skateboarder (Chambers, 2003).

By observing video clips one simple application to improve the kickflip is to "get low" and bend knees prior to the maneuver.

Training and Coaching Implications

The lower body coordination and technique, used by experts in this study, was primarily simultaneous and very similar to that of the vertical jump (Bobbert & van Ingen Schenau, 1988; Hatze, 1998; van Ingen Schenau, 1989). Skateboarders generally are not seen as those athletes who train in the gym or perform exercises to increase their ability. This study allows us to say that theoretically since the movement is similar to that of the vertical jump, all of the training research that has been done to improve vertical jumps can improve the efficiency and ability of the skateboarder to perform maneuvers of many variations, including the kickflip.

Some recommendations for vertical jump training are consecutive jumping drills such as jumping rope, countermovement jumps, traveling squats and heel raises. These tips are given validation by the meta-analysis study done by Markovic (2007) where he states that plyometric training provides a statistically significant and practically relevant improvement in vertical jump height with the mean effect ranging from 4.7% (Squat Jump and Drop Jump), over 7.5% (Counter Movement Jump with Armswing) to 8.7% (Counter Movement Jump). Squat and balance training would also be useful to the "get low" aspect of performing the maneuver. These results justify the application of plyometric training for the purpose of development of vertical jump performance in healthy individuals.

For future educators it will be important to have knowledge if this growing sport. Skateboarding is growing out of its infancy and the progression of the sport is now advancing.

Recommendations for Future Research

1. Increase number of participants.
2. A closer representative sample of the general demographic of traditional skateboarders, which is in flux but as of now is younger and has less mass.
3. Include women in the study, and/or conduct same research and compare men to women.
4. Including landing data could show more kinematics and forces of interest.
5. Use same subjects in a vertical jump test to have coordinated data that may show strength measures of the participant.
6. Include upper body kinematics.

Summary

In order for a skateboarder to perform a kickflip certain kinematics and a technique are achieved with time. Studying these kinematics and forces will allow for future achievement in the sport. The majority of skateboarders continue to meet this achievement of a kickflip conventionally “successful”, watching and waiting to be able to discern another skateboarder’s motion. All types of strategies produce results, but it is the ability to consistently reproduce abilities to pass on the sport of skateboarding.

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APPENDICIES

Appendix A

Consent Form

Barry University
Informed Consent Form

Your participation in a research project is requested. The title of the study is The Kinematics and Ground Reaction Force Analysis of Skateboarders with Varying Years of Experience Performing the Kickflip Maneuver. The research is being conducted by Nicole Jacobs, a student in the Sport and Exercise Sciences department at Barry University, and is seeking information that will be useful in the field of Biomechanics. The aims of the research are to fill a large gap of information in the biomechanical perspective in the sport of skateboarding.

In accordance with these aims, the following procedures will be used:

If you decide to participate in this research, you will be asked to do the following: You will report to the biomechanics laboratory for testing at a previously assigned time. After reading and signing the informed consent form, you will be asked to change into snug fitting dark colored and sleeveless tees and/or remain shirtless. Before data is recorded, you will be given time to familiarize yourself with the laboratory setting and be given a full description of precisely what would be asked of you for you attempts at the kickflip trials. It will be determined if you have basic safety skills of skateboarding e.g.; how to stop properly, proper performance of slowing and turning techniques, and how to fall safely.

Reflective markers will be placed laterally on your body on your shoulder, the greater trochanter (hip), the lateral femoral condyle (knee), and on the lateral malleolus (ankle) and your 2nd metatarsal head (toe). You will have any additional time needed to adjust to performing while wearing them.

This participation will take approximately take 30 minutes of your time.

No other instruction or restriction will be given.

We anticipate the number of participants to be 12.

You will be videotaped during data collection and 2 successful kickflips will be recorded.

Your consent to be a research participant is strictly voluntary and should you decline to participate or should you choose to drop out at any time during the study, there will be no adverse effects on you or student standing at Barry University if you are a student

The risks of involvement in this study are moderate, that is risks are significant but there is adequate surveillance to discover adverse events and adequate protections to control and keep their effects minimal. The risks may include bruising and sprains. The following procedures will be used to minimize these risks: Mats will be provided to cushion falls, if any. Safety gear such as a helmet, knee pads and elbow pads will be provided and must be worn during participation. You must wear your own properly fitted sneakers. Minimum basic first aid will be provided and if outside emergency help is called you will be the bearer of the cost. The benefits to you for participating in this study will be a chance at the raffle (1 in 12) of the skateboard used during participation. An indirect benefit will be providing knowledge to the advancement of the sport of skateboarding.

As a research participant, information you provide will be held in confidence to the extent permitted by law. Any published results of the research will refer to group averages only and no names will be used in the study. Data will be kept in a locked file in the researcher's office. The videotape made will be destroyed after 1 year. Your signed consent form will be kept separate from the data.

If you have any questions or concerns regarding the study or your participation in the study, you may contact me, Nicole Jacobs, at 305.308.3736, my supervisor Dr. Kathy Ludwig, at 305.899.4077, or the Institutional Review Board point of contact, Mrs. Nildy Polanco, at (305)899-3020. If you are satisfied with the information provided and are willing to participate in this research, please signify your consent by signing this consent form.

Voluntary Consent

I acknowledge that I have been informed of the nature and purposes of this experiment by _________ and that I have read and understand the information presented above, and that I have received a copy of this form for my records. I give my voluntary consent to participate in this experiment. I attest that I am 18 years of age or above, have performed a kickflip from a rolling position numerous times and have at least two years experience in the sport of skateboarding and am in good health with no current or history of injury that may affect my performance.

______________________ __________

Signature of Participant *Date*

______________________ __________ ______________________ __________

Researcher *Date* *Witness* *Date*

(Witness signature is required only if research involves pregnant women, children, other vulnerable populations, or if more than minimal risk is present.)

Appendix B

Protocol Form

Barry University

Research with Human Participants Protocol Form

PROJECT INFORMATION

1. **Title of Project** A Kinematic and Ground Reaction Force Analysis of Skateboarders with Varying Years of Experience Performing the Kickflip Maneuver.

2. **Principal Investigator** Nicole Jacobs

Student Number or Faculty Number: 118-66-4243
School – Department: Human Performance and Leisure Studies
Mailing Address: 1262 Pennsylvania Ave #16, Miami Beach, FL 33139
Telephone Number: 305.308.3736
E-Mail Address: JacobsN@bucmail.barry.edu

NOTE: You ***WILL NOT*** *receive any notification regarding the status of your proposal unless accurate and complete contact information is provided at the time the proposal is submitted.*

3. **Faculty Sponsor** Kathy Ludwig

School – Department: Human Performance and Leisure Studies
Mailing Address: 11300 NE Second Avenue, Miami Shores, FL 33161
Telephone Number: 305.899.4077
E-Mail Address: kludwig@mail.barry.edu

Faculty Sponsor Signature:________________________________ Date: _____________

4. **Member of Thesis Committee: Yes __X___ No: ________**

5. **Funding Agency or Research Sponsor**

6. **Proposed Project Dates**

Start _November 13, 2007________________

End _November 13, 2008_______________

Note: It is appropriate to begin your research project (i.e., the data collection process) only *after* you have been granted approval by this board. Proposals that list starting dates occurring before the date of submission will be returned without review. Please allow time for approval when determining your start date. It is best if the end date you choose is one year after the start date.

Please Provide the Information Requested Below

A. Project activity STATUS is: (Check one of the following three as appropriate.)

_X_ NEW PROJECT
___ PERIODIC REVIEW ON CONTINUING PROJECT
___ PROCEDURAL REVISION TO PREVIOUSLY APPROVED PROJECT
(Please indicate in the **PROTOCOL** section the way in which the project has been revised.

B. This project involves the use of an **INVESTIGATIONAL NEW DRUG (IND) OR AN APPROVED DRUG FOR AN UNAPPROVED USE** in or on human participants.
___ YES __**X**_NO
Drug name, IND number and company: ____

C. This project involves the use of an **INVESTIGATIONAL MEDICAL DEVICE (IMD)** or an **APPROVED MEDICAL DEVICE FOR AN UNAPPROVED USE.**
___ YES _**X**__NO

D. This project involves the use of **RADIATION** or **RADIOISOTOPES** in or on human participants.
___ YES _**X**_ NO

E. This project involves the use of Barry University students as participants. (If any students are minors, please indicate this as well.)
_X_ YES Barry Students will be participants (Will minors be included? ___ YES **_x_** NO)
___ NO Barry Students will participate

F. **HUMAN PARTICIPANTS** from the following population(s) would be involved in this study:

___ Minors (under age 18)
___ Abortuses
___ Prisoners
___ Mentally Disabled
___ Other institutionalized persons (specify)
__X_Other (specify) __People from a local skatepark____
___ Fetuses
___ Pregnant Women
___ Mentally Retarded

G. Total Number of Participants to be Studied: ___12______

Description of Project

1. **Abstract** (200 words or less)

The purpose of this study was to begin to fill the gap of information that exists in biomechanically quantifying the sport of skateboarding. Skateboarding has several million regular participants in the US alone and a relatively high incidence of injury (Kyle *et al*., 2002). Many of these injuries are the result of un-controlled landings and what can be assumed take-off forces produced to accomplish certain maneuvers. With 13 million people averaged to be skateboarders there is a gap in information related to quantifying this sport. In this current study, focus was geared towards the maximal take-off forces generated by the kickflip maneuver as well as lower body kinematics. Five male skateboarders with less than 2 years of experience and 5 male skateboarders with more than 2 years experience will participate. A multi-component force plate (AMTI 4507) was used. The plate will record data in the Z axis for vertical force. Ground reaction forces will be recorded directly into the computer program through an A/D converter. The ground reaction forces will be amplified (SGA6-4) with a gain set at 4000 Hz. The skateboarders will be asked to perform a successful kickflip maneuver on the force platform while on their skateboard. Peak forces will be computed to compare the two groups of experience levels in the take-off phase only. Lower extremity kinematics will also be calculated to provide body orientation in the air at take-off phase and fully airborne.

2. **Recruitment Procedures**

The investigator will contact a local skateboarding shop to requite participants (please see attached script). Barry University students will also be asked by the investigator through word of mouth spread to interested participants.

Script: Hello, my name is Nicole Jacobs, a graduate student in the program of Biomechanics at Barry University. I am here to request your participation for a study I am conducting for completion of my Masters degree.

My study is entitled A Kinematic and Vertical Ground Reaction Force Analysis of Skateboarders with Varying Years of Experience Performing the Kickflip Maneuver.

-I need participants who are 18 years of age or older.

-You must be able to perform a rolling kickflip.

-You must have 2 years of skateboarding experience and posses the knowledge of basic stopping, turning and safe falling skills.

-You will be wearing protective gear: helmet, knee and elbow pads; which are provided or wear your own.

-You will be asked to sign a consent form which details the steps of participation and what will take place during the experiment.

-A benefit for participation is in the raffle of the skateboard used for participation where you will have a 1 in 12 chance of winning.

THANK YOU.

3. Methods

The purpose of this study is to examine vertical ground reaction forces (VGRF) and body kinematics of a kickflip maneuver to examine the technique of novice and experienced skateboarders. Examination of the vertical ground reaction force at take-off for a skateboarder to perform the desired maneuver is critical in providing data that indicates impact on the body. This data can be used to reduce injury, enhance performance and increase the longevity of the skateboarder. Studying the kinematics will provide us with a possible pattern of movement of the body segments.

Participants

Twelve (12) healthy, uninjured in the past 6 months, male skateboarders will be recruited for this study. Male participants were used to avoid differences in angular kinematic data that can be attributed to gender differences. All participants will be recruited from local skateboard shop. All skateboarders had varying levels of experience and were broken into 2 groups. One group experience level was at least 2 years or less and the other had more than 2 years experience. All participants will be asked to read and sign an informed consent form detailing the study's procedures, as well as any risks and consequences of the study.

Instruments

The study will incorporate the use of four JVC 60 Hz video cameras. The cameras are placed in the four corners of the laboratory, a facility with an approximate size of 8 x 14 ft.

They will be placed at the approximate height of 1.5 m. A calibration module with an approximate size of 2 x 2 x 2 m and containing 21 balls with known coordinates will be used to calibrate the cameras. The module and all of the kickflip maneuvers will be videotaped, and the images on the tapes were transferred into a computer, then later digitized and analyzed using Peak Motus Ver. 8.2 (Vicon Peak Perform Tech, Inc., Centennial, CO) motion analysis software. A multi-component force plate (AMTI 4507) will be used. The plate will record data in the Z axis for vertical force. Ground reaction forces will be recorded directly into the computer program through an A/D converter. The ground reaction forces will be amplified (SGA6-4) with a gain set at 4000 Hz. Kinematic and reaction force data will be synchronized at the time of initial contact with the force plate. The skateboarders will perform a kickflip on top of the force platform all with the same skateboard. The model of skateboard was the *Zero* 8.0 weighing 5 lbs. and 32 inches long.

Procedures

Each participant will report to the biomechanics laboratory for testing at a previously assigned time. After reading and signing the informed consent form, the skateboarders will be asked to change into snug fitting dark colored and sleeveless tees and/or remain shirtless. Before data is recorded, all participants were given time to familiarize themselves with the laboratory setting and be given a full description of precisely what would be asked of them for their trials. The skateboarders will go over the force place for timing to be able to perform with both back wheels on the force plate at the time of take-off.

Reflective markers will be placed laterally on the side of body that will have the corresponding foot on the back of the board at take-off on the shoulder, the greater trochanter (hip), the lateral femoral condyle (knee), and on the lateral malleolus (ankle) and the 2nd metatarsal head (toe). After the markers are placed on the participant, any additional time needed to adjust to performing while wearing them was given.

In the take-off and airborne phase, no instruction will be given to restrict trunk lean; this aspect is up to the individual. Hip, knee and ankle flexion also have no restrictions. The subjects are allowed to perform the maneuver twice and only one successful trick completion, based on what the participant felt was most natural, will be reported. No other instruction or restriction will be given.

Design and Analysis

After the entire session for a skateboarder will be videotaped, the footage will be cropped to include only data needed from the contact of the board with the force plate needed for synching purposes through the tenth frame after subject was fully airborne. All points for which the reflective markers were used will be digitized automatically.

Individual differences occur among skateboarders that usually result in unique body orientations in which to accomplish their goal, this also called technique. The independent variables are the skill level of the skateboarder, experience and novice. The dependent variables are the range of motion (ROM) of the trunk, hip, knee and ankle from maximum flexion to take-off. Angular velocities of the trunk, hip, knee and ankle at take-off will also be reported. And the SPC between the trunk and hip, hip and knee and knee and ankle will be reported.

The knee angle will be calculated as a vector angle between the greater trochanter, the knee and the malleolus. The points connecting the hip and the shoulder will represent the trunk.

Shared positive contribution (SPC) will be calculated between each of the fore mentioned angle and segment among the amateurs and the experienced skateboarders. SPC will be calculated between the two groups of skateboarders at the knee angle and body segment movements. SPC will be computed by dividing the time that both segments were in simultaneous propulsion (velocities are positive and increasing) by the time that either segment is in propulsion (Bird, Hill, & Hudson, 1991). There is a difference between SPC of proximal to distal initiation and SPC of distal to proximal initiation (Smith & Wilkerson, 1997). The SPC of distal to proximal initiation were subtracted from 200 and expressed as a value between 100 and 200. For example, an SPC of 50% (proximal to distal) is recorded as 50% whereas an SPC of 50% (distal to proximal) is recorded as 150%. Any value over 100% indicates a distal to proximal initiation and a characteristically an immature pattern of coordination. The following classifications were used assessing the overall coordination of the skill: (a) sequential pattern, 0%-33% SPC; (b) intermediate pattern, 34%-66% SPC; (c) simultaneous pattern, 67% - 100% SPC; and (d) jerky pattern (distal-proximal) 101%-200 SPC (Smith and Wilkerson, 1997).

The hypotheses of no significant differences between novice and experienced skateboarders of all dependent variables will be tested using a Holtelling's T-test ($p<.05$). Statistical data will be calculated through the SPSS version 14.0 for Windows.

EMERGENCY PLAN OF ACTION

In case of emergency where bodily harm/injury has taken place:

1. Call 911 from phone located in Biomechanics Lab, or cell phone.
2. Tell injured to remain still and immobile.
3. Call 305.899.3333 or *3 from local line for campus security.

4. **Alternative Procedures**

Participants can opt out at any time with no penalties against them.

5. **Benefits**

A benefit of the participant will be the chance (1 in 12) at the raffle of the skateboard used for participation. Another benefit is the knowledge of performance they main gain through careful observation and performance of the maneuver.

6. **Risks**

The risks of involvement in this study are moderate, that is risks are significant but there is adequate surveillance to discover adverse events and adequate protections to control and keep their effects minimal. The risks may include bruising and sprains. The following procedures will be used to minimize these risks: Mats will be provided to cushion falls, if any. Safety gear such as a helmet, knee pads and elbow pads will be provided and must be worn during participation. You must wear your own properly fitted sneakers. Minimum basic first aid will be provided and if outside emergency help is called you will be the bearer of the cost. The benefits to you for participating in this study will be a chance at the raffle (1 in 12) of the skateboard used during participation. An indirect benefit will be providing knowledge to the advancement of the sport of skateboarding.

7. **Anonymity/Confidentiality**

Names will not be recorded with corresponding data. Findings of the study will be published with no identifiers. The signed consent forms will be kept separate from data, and kept in the locked Biomechanics Lab. Videos will be kept in the lab as well and destroyed after 1year.

8. **Consent**

Attach a copy of the consent form(s) to be signed by the participant and/or any statements to be read to the participant or informational letter to be directed to the participant. **(A copy of the consent form should be offered to each participant.)** If this is an anonymous study, attach a cover letter in place of a consent form.

9. Certification

I certify that the protocol and method of obtaining informed consent as approved by the Institutional Review Board (IRB) will be followed during the period covered by this research project. Any future changes will be submitted to IRB review and approval prior to implementation. I will prepare a summary of the project results annually, to include identification of adverse effects occurring to human participants in this study. I have consulted with the department or program faculty/administrators and the Dean of the school which is to be the subject of research and have received prior approval to conduct the research and/or to disseminate the results of the study. A copy of that approval has been included with this protocol.

________________________________ ____________________

Principal Investigator *Date*

***Reminder*: Be sure to submit fifteen (15) individually collated and bound (i.e. stapled or paper clipped) copies of this form with your application.**

*NOTE: Your proposal **WILL NOT** be reviewed until the completed packet is received in its entirety.*

Appendix C

Participant Questionnaire

Hello, my name is Nicole Jacobs, I am a Biomechanics Graduate student at Barry University here in Miami, studying the body mechanics of skateboarders.

Please fill out the form below…

Name ____

Age _____

Weight _____

Height_____

Are you regular or goofy foot?____________________________

What is your dominant foot?______________________________

Contact Info (cell phone/email)

____

Have you skateboarded in a competition before? ______________

How many years have you been skateboarding? ______________

How many years have you been able to perform the kickflip?________

THANK YOU for your time.

Appendix D

Thesis in Article Format

A Kinematic and Vertical Ground Reaction Force Analysis of Skateboarders with Varying Years of Experience Performing the Kickflip Maneuver

NICOLE JACOBS

Abstract

The purpose of this study was to begin to fill the gap of information that exists in biomechanically quantifying the sport of skateboarding. Skateboarding has several million regular participants in the US alone and a relatively high incidence of injury (Kyle *et al*., 2002). Many of these injuries are the result of un-controlled landings and what can be assumed take-off forces produced to accomplish certain maneuvers. With 13 million people averaged to be skateboarders there is a gap in information related to quantifying this sport. In this current study, focus was geared towards the maximal take-off forces generated by the kickflip maneuver as well as looking at net joint moments produced. Three male skateboarders with less than 2 years of experience and three male skateboarders with more than 2 years experience participated. A multi-component force plate (AMTI 4507) was used. The plate recorded data in the Z axis for vertical force. Ground reaction forces were recorded directly into the computer program through an A/D converter. The ground reaction forces were amplified (SGA6-4) with a gain set at 4000 Hz. The skateboarders were asked to perform a successful kickflip maneuver on the force platform while on their skateboards. Peak forces were computed to compare the two groups of experience levels in the take-off phase only. Lower extremity kinematics were also calculated to provide body orientation in the air at take-off phase. Shared positive contribution (SPC) was also calculated to show the intersegmental coordination of the lower limbs. One-way MANOVAs were used to calculate; range of motion of the hip, knee and ankle; the hip, knee and ankle take-off angles; and the SPC of the hip to knee, and the knee to ankle. The vertical ground reaction force was statistically determined by a univariate ANOVA. Results found no significance difference in the above parameters but trends were discovered.

Keywords: Skateboarding, vertical ground reaction force, kinematics

Introduction

Epidemiological studies characterize skateboarding as an activity with a relatively high incidence of injury (Kyle, Nance & Rutherford (2002); Osberg, Schneps, Di Scala, Li (1998)). Given these clinical concerns and the fact that this sport has an estimated participation level of 13 million in the United States alone, it is surprising that so little is known about the biomechanics of this growing sport. Similarly a study done by Everett, 2002, reported high incidences of injury. The study reported incidences of injury at the emergency department near a local commercial skate park in California. Over one year, 102 episodes were recorded, representing 106 injuries. There was incidence of musculoskeletal injuries, which accounted for 80% of the visits to the emergency department, fractures and dislocations, and facial and abdominal injuries. A substantial number of injuries occurred at the skate park, despite controlled conditions and equipment requirements. This information raises the question of technique of the skateboarders and if proper instruction and training was known and given, and whether the future of the skateboarder's health and the life of the sport can continue with minimized risk and increase in performance value of the skateboarders.

A Kickflip is thought to be the most difficult of the basic maneuvers/tricks used by skateboarders. The maneuver is complex and precisely coordinated. To execute the kickflip the skateboarder must begin with an Ollie, and then flick the board with the foot to make it spin underneath while in the air. In a clean kickflip, the skater kicks the board with the top and side of his or her front foot, the skateboard flips and spins over at least once, and the skateboarder lands on the skateboard comfortably, wheels down, and rides away.

Among the few biomechanical studies on skateboarding reported that resulting vertical ground reaction forces (VGRF) observed during the performance of an Ollie take-off have a characteristic two-humped shape (Frederick et al, 2006). Vertical ground reaction force values provide information as to how much force the subject is placing downwards in order to produce the action. These force values may not always predict the subject's overall jumping ability, strength, muscle mass and training regimen are also determinants to a subject's jumping ability. Fredrick and Determan did not describe the technique of the Ollie or the kickflip, which leaves a substantial hole in knowledge of how these tricks are accomplished.

Methods

Participants consisted of six (6) male skateboarders with at least two years of skateboarding experience and varying levels of accomplishment of the performance of the kickflip. The two groups were separated in novice v. experienced based on the number of successful landings of the kickflip conducted in the pretest of best of eleven attempts. Those skateboarders who landed five (5) or less out of eleven (11) attempts of the kickflip were placed in the novice group. Those skateboarders who landed six (6) or more out of eleven (11) kickflips were placed in the experienced group. The two groups consisted of three (3) skateboarders each.

The study incorporated the use of four JVC 60 Hz video cameras. The cameras were placed in the four corners of the laboratory, a facility with an approximate size of 8 x 14 ft. They were placed at an approximate height of 1.5 m. A calibration module with an approximate size of 2 x 2 x 2 m and containing 21 balls with known coordinates was used to calibrate the cameras. The module and all of the kickflip maneuvers were videotaped, and the images on the tapes were transferred into a computer, then later digitized and analyzed using Vicon Peak Motus Ver. 8.2 (Vicon Peak Perform Tech, Inc., Centennial, CO) motion analysis software. A multi-component force plate (AMTI 4507) was used. Ground reaction forces were recorded directly into the computer program through an A/D converter. The ground reaction forces were amplified (SGA6-4) with a gain set at 4000 Hz. Kinematic and reaction force data were synchronized at the time of initial contact with the force plate. The skateboarders performed a kickflip on top of the force platform. All participants used the same skateboard. The skateboard deck used was a Hopps Deck, 31.5 inches X 7.6 inches. 7/8 Allen hardware was used with Bones Red bearings, Habitat 52mm wheels and Independent 129 trucks. The skateboard weighed 5 lbs.
Each participant reported to the biomechanics laboratory for testing at a previously assigned time. After reading and signing the informed consent form, the skateboarders were asked to change into snug fitting dark colored and sleeveless tees and/or remain shirtless. A helmet,

elbow pads and knee pads were provided and used by the skateboarders for safety. Before data was recorded, all participants were given time to familiarize themselves with the laboratory setting and be given a full description of precisely what would be asked of them for their trials. The skateboarders went over the force place for timing to be able to perform with both back wheels on the force plate at the time of take-off.

Reflective markers were attached with an adhesive sticker with reflective marker attached laterally on the side of body that had the corresponding foot on the back of the board at take-off on the shoulder, the greater trochanter (hip), the lateral femoral condyle (knee), and on the lateral malleolus (ankle). After the markers were placed on the participant, any additional time needed to adjust to performing while wearing them was given.

No instruction was given on how to complete the kickflip. The subjects were allowed to perform the maneuver in two acceptable trials, based on what the participant felt was most natural, and were videotaped and analyzed. No other instruction or restrictions were given.

After the entire session for a skateboarder was videotaped, the footage was cropped to include only data needed from the contact of the board with the force plate needed for synching purposes through the tenth frame after subject was fully airborne. All points for which the reflective markers were used were digitized automatically.

Individual differences occur among skateboarders that usually result in unique body orientations in which to accomplish their goal, this also called technique. The independent variable is the skill level of the skateboarder, experience and novice. The dependent variables were the range of motion (ROM) of the hip, knee and ankle from maximum flexion to take-off. Angular velocities of the hip, knee and ankle at take-off were also calculated. And the SPC between the hip and knee, and knee and ankle were also reported. (See figure 3 below).

Results

Table 1.
Demographic Data of the Participants

Variable	Novice		Experienced	
	Mean	SD	Mean	SD
Age (yrs)	28.3	.9	26.6	3.5
Weight (kg)	73.1	2.8	65.5	3.9
Height (cm)	185.1	1.1	169.3	1.7
Years of Experience	15.7	2.0	14.3	2.9
Years of Kickflip Experience	8.5	1.6	12.7	2.2

*All subjects were regular footed
*All subjects were right foot dominant

As can be seen by viewing Table 1 mean age, mean weight, and mean height were all relatively close among the groups. A main focus and point of interest of the demographic data is that of the years of experience in skateboarding and that of the years of experience in being able to perform the kickflip. Overall, the group with more years of skateboarding experience had less years of kickflip experience, the novice group. In contrast, the group with less years of skateboarding experience had more years of kickflip experience, the experienced group.

Take-off in this study is defined as the point in time where the skateboarder left contact of the board in air while performing the kickflip. This take-off point occurs after maximum VGRF has been reached (See figures 4 & 5).

Figure 4. Approach - Novice

Figure 5. Take-off - Novice

As seen in Figure 5, the novice kickflipper has his wheels off the force plate only and inch or two and foot contact with the board occurs very close to the board while limbs are relatively straight.

Figure 6. Approach - Experienced

Figure 7. Take-off - Experienced

Figure 7 provides a visual that shows the experienced kickflipper has popped his board more than the novice, which indicates more force produced, and therefore is in the air about 6 inches off the ground before he begins his flick of the board. His limbs have grater flexion and range of motion than the novice.

The average maximum VGRF was greater from the experienced group v. the novice group (2211.09 N v. 1949.609 N, 3.4 BW v. 2.7 BW). See table 2 below.

Table 2. Maximum Vertical Ground Reaction Forces (VGRF in Newtons, N) and (Body Weights, BW) and Means

Novice		Experienced	
Subject 2	1791.96 N, 2.4 BW	*Subject 1*	2147.09 N, 3.3 BW
Subject 5	2396.55 N, 3.6 BW	*Subject 3*	1820.57 N, 3.2 BW
Subject 6	1660.32 N, 2.2 BW	*Subject 4*	2665.61 N, 3.8 BW
Mean	**1949.61 N (2.7 BW), SD 392.62 N**	**Mean**	**2211.09 N (3.4 BW), SD 426.14 N**

The mean ROM of as depicted in Figure 4 to 5 and Figure 6 to 7 is greater in the experienced v. novice (See Table 3 and Figures 4, 5, 6 and 7). The mean range of motion of the novice group was less than the range of motion of the experienced group in the hip, knee and ankle. The mean ROM for the hip was 34.6° for novice and 75.6° for the experienced group. The experienced group had on average a 41.0° greater hip ROM than the novice group. The range of motion at the knee was 39.8° and 81.7° on average for the novice and experienced group respectively. The experienced group had a 41.8° average greater ROM at the knee than the novice group. And, the mean range of motion at the ankle was 33.6° for the novice group and 48.7° for the experienced group. The experienced group had a 15.2° greater ROM on average at the ankle than the novice group.

Table 3. Range of Motion of Joint Angles (Degrees ^{o})

Novice		Experienced	
Subject 2		**Subject 1**	
Hip	57.7	Hip	89.9
Knee	68.2	Knee	75.9
Ankle	50.2	Ankle	41.2
Subject 5		**Subject 3**	
Hip	5.9	Hip	53.7
Knee	15.6	Knee	79.5
Ankle	2.2	Ankle	60.9
Subject 6		**Subject 4**	
Hip	40.1	Hip	82.9
Knee	35.8	Knee	89.5
Ankle	48.2	Ankle	44.1
Hip	Mean 34.6 SD 26.3	Hip	Mean 75.6 SD 19.2
Knee	Mean 39.8 SD 26.5	Knee	Mean 81.7 SD 7.0
Ankle	Mean 33.6 SD 27.2	Ankle	Mean 48.7 SD 10.6

The take-off angles of the hip, knee and ankle provide data of the position of the body while in air before the flick stage of the maneuver (See Table 4).

At take-off, the point where the skateboarder left contact with the board while in air before the flick stage of the maneuver, on average the experienced group had greater joint ankles than the novice group at the hip, knee and ankle. The average angle at the hip was 124.64° for the novice group and 143.16° for the experienced group. The experienced group had an 18.52° average greater angle than the novice group at the hip. The average angle at the knee was 121.07° for the novice group and 139.73° for the experienced group. The experienced group had an 18.66° average greater angle than the novice group at the knee. The average angle at the ankle was 88.54° for the novice group and 108.12° for the experienced group. The experienced group had a 19.58° average greater angle than the novice group at the ankle.

Table 4. Take-off Angles of the Hip, Knee and Ankle (Degrees°)

Novice		**Experienced**	
Subject 2		**Subject 1**	
Hip	157.3	Hip	152.8
Knee	161.3	Knee	140.9
Ankle	115.3	Ankle	98.4
Subject 5		**Subject 3**	
Hip	99.3	Hip	135.6
Knee	76.5	Knee	143.3
Ankle	77.1	Ankle	120.7
Subject 6		**Subject 4**	
Hip	117.4	Hip	141.1
Knee	125.4	Knee	134.9
Ankle	73.3	Ankle	105.2
Hip	Mean 124.7 SD 17.1	Hip	Mean 143.2 SD 5.0
Knee	Mean 121.1 SD 24.6	Knee	Mean 139.7 SD 2.5
Ankle	Mean 88.6 SD 13.4	Ankle	Mean 108.1 SD 6.6

The SPC of *novice* skateboarders is intermediate in pattern as it is simultaneous with segments contributing differently from subject to subject. The SPC of *experienced* skateboarders is all simultaneous in pattern with the one exception of one skateboarder in knee to ankle pattern (See Table 5).

As seen in Table 5, the SPC for Subject 2 had an intermediate pattern classification from the hip to knee and a simultaneous pattern classification from the knee to ankle. Subject 5 had a simultaneous pattern classification from the hip to knee and an intermediate pattern classification from the knee to ankle. Subject 6 had a simultaneous pattern classification from the hip to knee and an intermediate pattern classification from the knee to ankle.

Table 5. Shared Positive Contribution (%) and classification pattern

Novice		
	%	Classification Pattern
Subject 2		
Hip to Knee	65%	intermediate
Knee to Ankle	100%	simultaneous
Subject 5		
Hip to Knee	89%	simultaneous
Knee to Ankle	57%	intermediate
Subject 6		
Hip to Knee	80%	simultaneous
Knee to Ankle	50%	intermediate
Experienced		
	%	Classification
Subject 1		
Hip to Knee	68%	simultaneous
Knee to Ankle	54%	intermediate
Subject 3		
Hip to Knee	87%	simultaneous
Knee to Ankle	79%	simultaneous
Subject 4		
Hip to Knee	83%	simultaneous
Knee to Ankle	83%	simultaneous

These participants were all in the novice group. For the experienced group, all movement was considered simultaneous in pattern with the exception of knee to ankle in Subject 1. Figures 8 and 9 below depict an example of the angular velocity of the hip knee and ankle joints of the novice and the experienced skateboarder. By observing the overlap and the point at which the peaks of each joint reach their maximum velocity it can be determined how much each joint angle contributes positively throughout the movement. By observing when the peaks occur in time it can be determined if the movement is sequential (peaks reached at different times) or simultaneous (peaks reached at relatively the same time).

Figure 8.

Novice

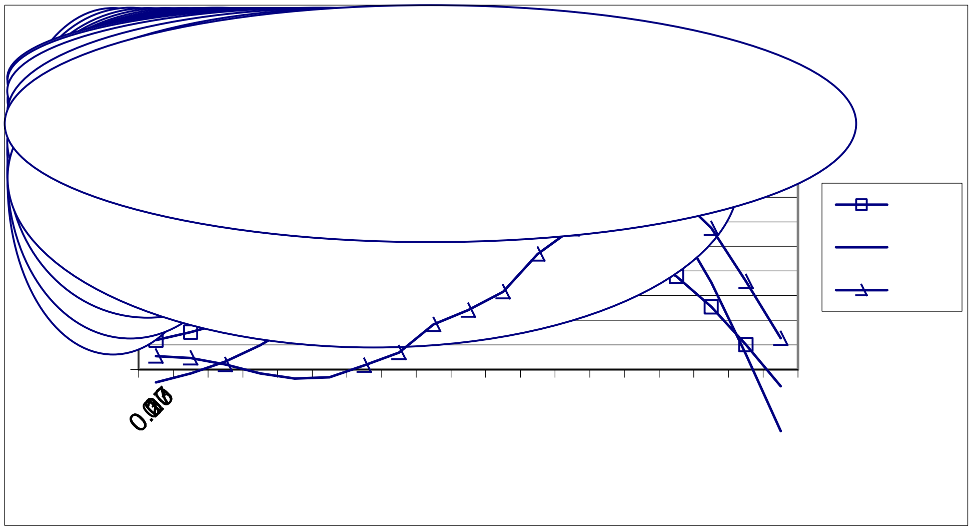
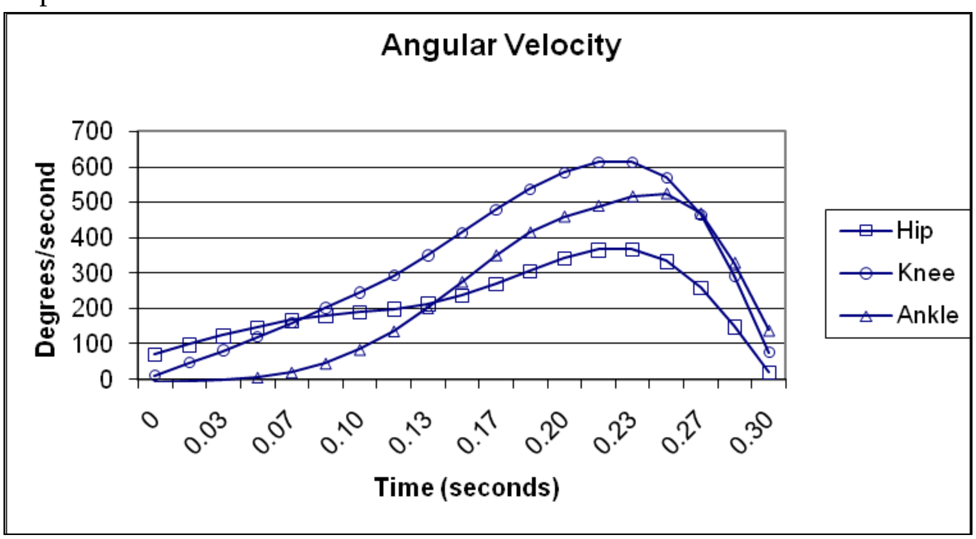


Figure 9.

Experienced



The Force-Time Curve graphs depict entire movement recorded from weight acceptance of the board to take-off of the kickflip (See Figures 10 and 11 of the subjects' force-time curve of their VGRF and Hip, Knee and Ankle Graphs.).

Figure 10.

Novice Group. Subject 5.

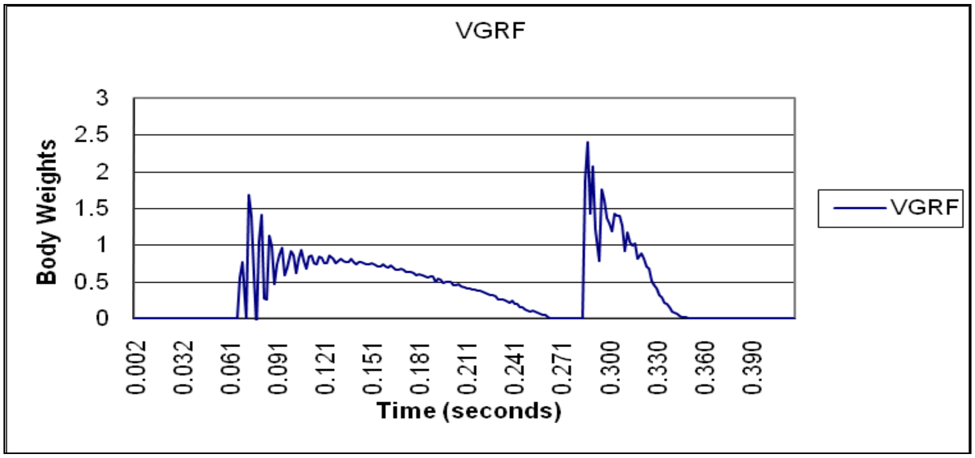
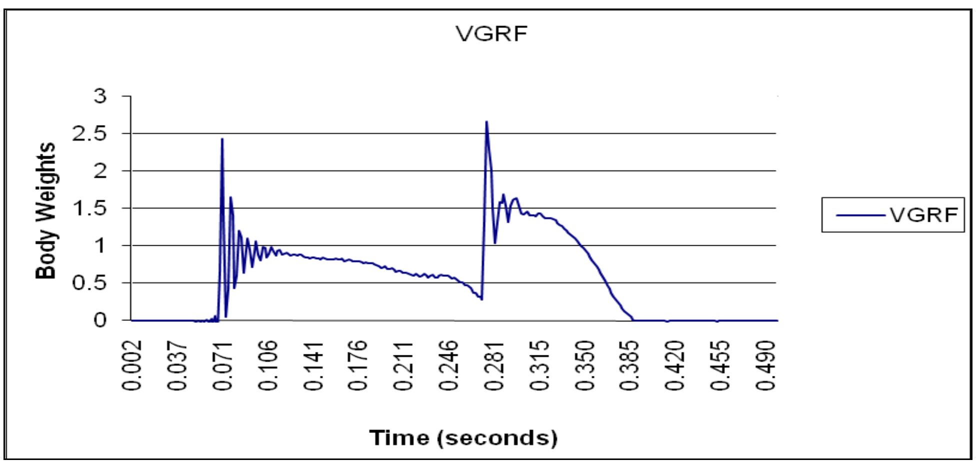


Figure 11.

Experienced Group. Subject 1.



The first VGRF peak, occurring after both wheels are on the force plate, is usually lower in magnitude than the second peak. This is followed by a force minimum, or at least a cessation of the rise in force, that is reached in between the two peaks. This appears to be a result of the unweighing of the board as the center of mass is lowered prior to the kickflip jump. This data coincides with findings of Fredrick et al 2006 and Determan et al 2006b in their studies done on the Ollie and the Kickflip. The second and usually higher magnitude peak is the result of force applied rapidly by the back foot to the tail of the board as it is rotated about the rear axel and slammed into the ground. The magnitude of these second propulsive peaks has a mean of 1949.609 N for the novice group and 2211.09 N for the experienced group. Typically the VGRF rose slightly above one bodyweight (BW) during the first 200-300 ms of the movement as the subject initially dorsi flexed their ankles on the skateboard before rapidly lowering their center of mass by flexing their ankles, knees, and hips. The VGRF then rose rapidly as the subjects jumped into the air off their back foot while their front foot controlled the motion and direction of the skateboard. This VGRF, the second hump, rose to around 3 or more times bodyweight.

An independent samples *t* test was calculated comparing the mean value of max VGRFs between groups novice v. experienced skateboarders. No significant difference was found ($t(1) = .478$, $p > .05$). The mean of the novice group (1) is 1949.61 Newtons with an SD of 392.6. The mean of the experienced group (2) was 2211.09 Newtons with a SD of 426.1.

A one way MANOVA was calculated examining the ROM of the hip, knee and ankle between groups. No significant effect was found (Hotelling's T (3,2) = .422 $p>.05$).

A one way MANOVA was calculated examining the take-off angles of the hip, knee and ankle between groups. No significant effect was found (Hotellling's T (3,2) =.377 $p>.05$).

A one way MANOVA was calculated examining the SPC of the hip to knee and the knee to ankle between groups. No significant effect was found (Hotelling's T (3,2) = .975 $p>.05$).

Discussion

One common maneuver in skateboarding is the kickflip. It is considered to be the most difficult of the easier maneuvers of the sport. Studies to date have not detailed the lower body kinematics and movement production used to accomplish the task of a kickflip. Forces have been analyzed but the technique of the movement has not been quantified until now, in this current study. It is hoped that this study would be of benefit to the scientific community as well as the skateboarders who wish to learn how to accomplish the goal of a kickflip. By studying the technique of the movement training implications were also found to help improve the accomplishment of the kickflip. This movement proved to be simultaneous in the experienced group of skateboarders and can be related to the vertical jump and its implications for training and optimal accomplishment.

Vertical Jump Relevance

The coordination of a maximal vertical jump from stance is very similar among individuals. This stereotyped execution of maximal vertical jump is reported to be the result of optimizing neuromuscular control through which one optimal solution for maximal jump height is reached (Bobbert & van Ingen Schenau, 1988; Hatze, 1998.) The optimal solution typically shows a proximal to distal sequence of segmental motions (Bobbert & van Ingen Schenau, 1988) and as a consequence the subject is able to keep contact with the ground until the hip and knee joint are nearly extended (van Ingen Schenau, 1989).

Another property of the musculo-skeletal system that can influence movement effectiveness is the horizontal orientation of the foot segment, which as instructed by the consensus of literature for the kickflip is very important. This is advantageous as the ankle is partially flexed in the initial stance phase on the skateboard. The necessary flexion prior to the jump is less important and required less in the hip and knee joints than in the ankle. As seen in the experienced subjects their degree of ankle flexion and ROM was greater than those of the inexperienced and greater than the change between the hip and the knee. Most work is therefore done with preciseness at the ankle.

Theoretically, an infinite number of strategies are possible to perform a vertical jump. However, this study showed consistency among subjects, suggesting that a certain criterion drives jumping strategy into a consistent pattern. That pattern varies among the two groups of novice and experienced. Vertical jump training would be advantageous but coordination is different because of the skateboard.

Similar Finding to Previous Studies

Amplitudes and force time curves of this study's dataset were very similar to those reported in previous studies. The kinematics of the maximal jump condition, i.e. joint angular displacements showed good agreement with those found by Bobbert and van Ingen Schenau (1988). And the kinetics of the jump condition, i.e. force produced at take-off, showed good agreement with those found by Determan, (2006a+b) and Fredrick, (2006).

Another musculo-skeletal property related to movement effectiveness is the initial foot segment orientation. The initial dorsi-flexed position of the ankle joint has an advantage compared to the hip and knee joints, as less flexion, is required before the joint is able to extend. This is shown in the relatively small changes in ROM at the ankle but it is none the less a critical if not the most important factor in accomplishing the kickflip. The experienced group relied heavily on their greater ROM and ankle flexion than the novice group.

When analyzing the previous findings, yet another property of the musculo-skeletal system which could influence the control of jumping is the fact that distal muscles have shorter muscle fibers and longer tendons compared to the proximal muscles (Yamaguchi, Sawa, Moran, Fessler & Winters, 1990; Voigt, Simonsen, Dyhre-Poullsen, & Klausen, 1995.) Vertical jumps, as in the kickflip as found in this study, are mainly performed by extending actions of the distal ankle joints, and consequently stretch-shortening of the distal muscle-tendon complexes. Muscles go through a stretch phase and then a contraction phase. Plyometric exercises are designed to shorten the cycle time between the two phases. A rapid cycle time allows maximum energy transfer between stretch and contraction phases. This leads us to the importance of training and strengthening these ankle muscles as defined, studied and determined through many vertical jump training exercises would also help improve the performance of the kickflip.

Trends from Video Evidence

The main findings of this present study were not statistically significant and had low power. However, the four main areas of interest can be discussed with some relevance based on the differences found between the groups in the data. The magnitudes of the VGRF during takeoff and landing were similar to previous studies by Frederick et al. data who studied skateboarders performing ollies up onto and off of a 45.7 cm wooden platform. In their study, take-off forces were found to be 2.22 BW's when their subjects first rolled onto a force plate and ollied up onto the platform. In this current study take-off force produced was between 2.7 and 3.4 BW's. Further analysis of this current study's VGRF data also shows the magnitudes and shape of the force-time curve are similar to other studies examining countermovement vertical jumps. McClay et al. (1994), studied vertical jumps in professional basketball athletes and found average take-off forces to be 1.7 ± 0.52 BW's and forces to be 4.3 ± 1.16 BW's, though no jump heights are reported. Dowling and Vamos (1993) examined vertical jumps of 97 young adults and found take-off forces ranging from 1.8 to 2.8 BW's for jump heights similar to those recorded in this study (2.7-3.4 BW's). The fact that ollie and kickflip movements so closely mirror other jumping movement sports such as basketball and volleyball, at least on a kinetic level, suggests that skateboarders may benefit from similar training exercises used in these more traditional sports to increase jump height ability. If skateboarders could increase their jumping ability they could theoretically be able to jump over higher objects with their boards or increase the number of revolutions the board completes during kickflips.

The participants in this study are not representative of a cross section of North American skateboarders. In a recent survey of 797 North American skateboarders, it was found that the average skateboarder was younger (mean age of 15 years 8 mos.) and lower in body mass (mean of 56.7 kg) than the experienced and more mature skateboarders in this study (Determan, 2006b). Caution needs to be exercised when applying the data collected in this study to the general population. Nevertheless, the task asked of the skateboarders to perform was not extreme and within the level of many typical skateboarders. The data of this study is scaled to body mass and finding of force are relative to those of the general skateboarding population.

The forces found in this study also support the need of manufactures of equipment to provide necessary footwear to ensure proper functional properties and properties to prevent damage to the immaturity of the skeletal system in the typical skateboarder (Chambers, 2003).

By observing video clips one simple application to improve the kickflip is to "get low" and bend knees prior to the maneuver.

Training and Coaching Implications

The lower body coordination and technique, used by experts in this study, was primarily simultaneous and very similar to that of the vertical jump (Bobbert & van Ingen Schenau, 1988; Hatze, 1998; van Ingen Schenau, 1989). Skateboarders generally are not seen as those athletes who train in the gym or perform exercises to increase their ability. This study allows us to say that theoretically since the movement is similar to that of the vertical jump, all of the training research that has been done to improve vertical jumps can improve the efficiency and ability of the skateboarder to perform maneuvers of many variations, including the kickflip.

Some recommendations for vertical jump training are consecutive jumping drills such as jumping rope, countermovement jumps, traveling squats and heel raises. These tips are given validation by the meta-analysis study done by Markovic (2007) where he states that plyometric training provides a statistically significant and practically relevant improvement in vertical jump height with the mean effect ranging from 4.7% (Squat Jump and Drop Jump), over 7.5%

(Counter Movement Jump with Armswing) to 8.7% (Counter Movement Jump). Squat and balance training would also be useful to the "get low" aspect of performing the maneuver. These results justify the application of plyometric training for the purpose of development of vertical jump performance in healthy individuals.

For future educators it will be important to have knowledge if this growing sport. Skateboarding is growing out of its infancy and the progression of the sport is now advancing.

Recommendations for Future Research

1. Increase number of participants.
2. A closer representative sample of the general demographic of traditional skateboarders, which is in flux but as of now is younger and has less mass.
3. Include women in the study, and/or conduct same research and compare men to women.
4. Including landing data could show more kinematics and forces of interest.
5. Use same subjects in a vertical jump test to have coordinated data that may show strength measures of the participant.
6. Include upper body kinematics.

Conclusions

In order for a skateboarder to perform a kickflip certain kinematics and a technique are achieved with time. Studying these kinematics and forces will allow for future achievement in the sport. The majority of skateboarders continue to meet this achievement of a kickflip conventionally "successful", watching and waiting to be able to discern another skateboarder's motion. All types of strategies produce results, but it is the ability to consistently reproduce abilities to pass on the sport of skateboarding.

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