THE EFFECTS OF PROPHYLACTIC ANKLE BRACING ON KNEE AND HIP MECHANICS IN BASKETBALL PLAYERS DURING JUMP LANDING

By

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ABSTRACT

THE EFFECTS OF PROPHYLACTIC ANKLE BRACING ON KNEE AND HIP MECHANICS IN BASKETBALL PLAYERS DURING JUMP LANDING

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Background: Many athletes of various sports have been required to wear ankle braces for prophylactic uses. Ankle braces have been shown to decrease range of motion in all directions, which means the main force absorption mechanism of the ankle may be inhibited. This decrease in force absorption at the ankle may increase the mechanical demands at the more proximal knee and hip joints. In this study, the change in knee, hip and lower back mechanics will be investigated to gain understanding as to whether bracing the ankle could create a higher injury potential. **Methods:** In this study, 12 intercollegiate basketball players (6 female, 6 male) participated during one session, in which each subject tested for each taping condition (self-adherent, adhesive cloth, and no tape). For each trial, the participants performed three maximum vertical jump trials and three depth drop trials, a 15-minute bout of exercise, and subsequently three more maximum vertical jumps and three more depth drops. The participants' lower body kinematics and kinetics were measured using 3D motion capture and force plates. **Results:** Analysis of ankle bracing pre- and post-exercise on lower extremity kinematics and kinetics through a two-way MANOVA yielded results that were not significant for any of the variables, including their interaction effect. There was no effect of the three different types of ankle bracing (control, adhesive, and self-adhesive), exercise (pre-and post-), or the interaction of those variables on peak hip flexion, peak knee flexion, peak knee moment, peak hip moment, and peak lumbosacral moment. **Conclusion:** Ankle bracing had no effect on selected lower body kinematics and kinetics. More research should be done to better understand whether ankle bracing has the potential to increase injury at other joints.

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INTRODUCTION

One of the most prevalent sources of injury in athletes is a lateral ankle sprain. In the physical activity setting, 15% to 30% of all injuries are to the ankle (Ibrahim, 2015). These injuries are typically caused by excessive inversion and plantarflexion of the ankle (Arnheim, 1993). Resultant strain on the ligaments and surrounding soft tissue create the most common symptoms: swelling and pain (Lassiter, Malone, Garrett, 1989). This type of injury can cause athletes to be out of play during crucial parts of the season. Once the acute phase of the ankle injury has passed and swelling has decreased, rehabilitation strengthening exercises are implemented. These include working stabilizing muscles through proprioception exercises (Lassiter, Malone, Garrett, 1989; Long et al., 2017). Current protocol for small degree ankle sprains includes bracing and taping and immediate return to play. If not handled properly, ankle sprains can result in chronic ankle instability which makes the entire foot prone to chronic inflammation (Doherty, et al., 2016). To prevent this type of injury, athletes wear prophylactic ankle braces that range from lace-up braces to athletic taping of the ankle. These prophylactics have not only become commonplace, but are often required by coaches and athletic trainers.

The goal of the ankle bracing (lace-up or taping) is to restrict range of motion at the endpoints of normal range. To prevent sprain, the brace should stop the ankle from reaching a range of motion (ROM) that would be considered excessive to the point where soft tissue becomes stressed, producing injuries (Gerrick, 1978). Restricting the ankle in its normal ROM in the sagittal direction (specifically dorsiflexion) reduces the force absorbing capacity of the ankle (Gerrick, 1978; Gross, 1988). If ankle motion is restricted, inhibiting its capacity to absorb force, then other joints must absorb that force (Gross, 1988; Santos et al., 2004).

One of the primary mechanisms for excessive ankle inversion and plantarflexion occurs during a landing from a jump (Mabee & Mabee, 2008). During take-off, the ankle naturally inverts and plantar flexes to generate force (Mabee & Mabee, 2008). Due to this natural mechanism, the potential for excessively inverting and plantar flexing during landing also increases (Mabee & Mabee, 2008). The overall goal during landing is to reduce the momentum of the body by generating force using the joints of the lower body from the ankle all the way to the lower back. During this movement, force is transferred directly to soft tissues as they are stretched beyond normal limits as the force of the body and the impact are applied (Lassiter & Malone & Garrett, 1989). When wearing an ankle brace, the potential restriction of ROM will not only reduce the injury mechanism from occurring, but it could also potentially cause the ankle to decrease in its absorptive capacity (McCaw & Cerullo, 1999).

When an injury does occur, it is very common that other joints and movement patterns are altered. Force is transferred from distal to proximal joints. When force is absorbed through the ankle and its supporting structures, it is also transferred to the knee and then to the hip (Saunders, 1993). The movement patterns generated by each joint provide the work to efficiently absorb the impact as to not allow excess stress that could potentially be injury producing (Saunders, 1993). For example, greater hip and knee flexion upon landing allow for less force to be placed on surrounding structures of the knee that could potentially cause ACL injuries (Ewing, Begg, Galea, Lee, 2016; Paulson, 2011). Similarly, the ankle normally dorsiflexes during landing and helps to reduce the mechanical load placed on the knee and hip joints.

When body movements are restricted due to injury, weakness, or bracing, forces are not absorbed and transferred up the kinetic chain (McCaw & Cerullo, 1999; Paulson, 2011; Saunders, 1993). It has been found that when athletes wear knee prophylactics during a drop landing or a bout of jogging, a larger force is sustained from the hip because of the restricted motion of the knee (Campbell, Yaggie, Cipriani, D, 2016; Ewing, Begg, Galea & Lee, 2016). Specifically, the hip was found to absorb about 11% more force during an entire bout of hour-long jogging as a result of wearing a knee brace (Campbell & Yaggie & Cipriani, D, 2016). When wearing an ankle brace, ROM has been found to be restricted in all directions (McCaw & Cerullo, 1999). When landing, the ankle inverts and plantar flexes to absorb force (Garrick, 1978). The hip also rotates to absorb force up the kinetic chain (Saunders, 1993). If ankle movement, specifically in the sagittal direction, has been inhibited, then it is likely that force is not being absorbed as much as it would be during a non-braced condition (Rieman, Schmitz, Randy, Gale, McCaw, 2002). If the ankle inverts significantly less, it is possible due to this interrelatedness of segments that the hip will also rotate less.

Statement of the Problem

It is known that the restriction of the ROM during dorsiflexion, plantar flexion, inversion, and eversion, keep the ankle from producing excessive movements that could potentially cause injury (Gross, 1994). It is also known that these movements of the ankle allow that joint to effectively absorb force. Decreasing the degree of movement at the ankle limits the amount of force that it can absorb (Gross, 1988). The force is then transferred to the knee and hip further up the body. The hip absorbs the most force out of any other lower extremity joint upon landing (Doherty et al., 2017). However, it remains unclear how hip joint kinetics and kinematics are affected when ankle ROM is restricted. The effects of ankle bracing on knee and hip mechanics are controversial. If these mechanics change as a result of prophylactic ankle bracing, athletes who wear these braces may be exposed to an increased risk of injury

The purpose of this study is to investigate whether knee, hip and lower back mechanics change during jump landing as a result of ankle prophylactic bracing among intercollegiate basketball players.

Jump Landing Mechanics

The purpose of this study originates from the idea that kinetics and kinematics change when the ankle is braced. In order to understand how this change may occur, it is important to understand what normal mechanics of the body are when landing. The joints of the lower extremities function to decrease the momentum of the body during landing to absorb force. The mechanism of this absorption is though flexion of the ankles, knees, and hips (Decker, Torry, Wyland, Sterett & Steadman, 2003). If the knees are flexed to be greater than 90º it is classified as a soft landing. If the knees are flexed less than 90º then the landing is classified as a stiff landing (Devita & Skelly, 1992). The ankles will plantarflex upon initial ground contact and then continually increase in dorsiflexion until maximum knee flexion has been achieved and the center of mass has been decelerated to zero. The hip will flex upon landing, and depending on landing style (including varus or valgus at the knee) will abduct or adduct at initial ground contact (Decker et al., 2002; Kernozek, Torry & Iwasaki, 2008).

The flexor moments at each joint are felt as a result of the force generated from the landing (Decker et al., 2002). Peak hip flexor moments are larger than the peak plantar flexor moments for females while peak hip flexor moments are larger than the peak plantar flexor moments and the peak knee flexor moments for males. There are no differences found between males and females between the degree of moments at each joint (Decker et al., 2002). Rotational moments at each joint as well as transverse plane moments at the hip and knee reduce momentum to effectively absorb force (Kernozek et al., 2008). The degree of these moments has been found to be dependent on the strength of the external rotator muscles of the hip (Malloy, Morgan, Meinerz, Geiser & Kipp, 2016). If these normal mechanics change individually between conditions of wearing ankle prophylactics and not wearing them, then there can be said to be an increase in the forces acting on the body. Any increase in force on the body can create a potential to cause injury (Decker et al., 2002; Devita & Skelly, 1992; Malloy et al., 2016).

Ankle Bracing and Decreased Range of Motion

There are many different types of braces that athletes use, but it has been well established that when restricting the ankle in a brace, ROM will be affected in all directions (Greene et al., 2014; Klem et al., 2017; McCaw & Cerullo, 1999; Simpson et al., 2013). Specifically, it has been found that ankle bracing decreases dorsiflexion ROM by five degrees (McCaw & Cerullo, 1999). Not only is the ROM at the ankle decreased, but angular velocity is also decreased by about 110 degrees/sec. This specific kinematic variable is important in force absorption and generation (McCaw & Cerullo, 1999). Not only does bracing decrease ROM at the ankle, but also can decrease the ROM of the hip (Santos et al., 2004). This change in ankle kinematics has been seen in many different settings including vertical jump, drop landing, balance tasks, as well as cutting tasks (Greene et al., 2014; Long et al., 2017; McCaw & Cerullo, 1999; Santos et. al, 2004). It is, however, inconclusive whether force transferred from the ankle up the kinetic chain to the hip is significant enough to increase the risk of injury. At this time, due to the inconclusive evidence of harm created at other joints, coaches and trainers still require athletes to wear ankle braces during both practice and competition.

Ankle Bracing and Ground Reaction Forces

Ground reaction force is the amount of force exerted from the ground on the body. If ground reaction forces are high, more force is put on the body, increasing risk for injury. When landing from a jump, an impulse, the product of force and time, is applied to the body by the ground and acts to reduce the momentum and slow the body down. The impulse required to slow the body down is determined by the height of the jump and the body weight of the person. Because an impulse is the product of force and time, a person can reduce the force applied to the body during landing by increasing the time over which force is applied. However, recent research on running has shown that ankle bracing decreases the time to peak force and thus increased the peak force experienced by the body (Rieman et al., 2002). The dorsiflexion motion of the ankle allows for ground reaction force absorption. If this motion is hindered and the time to ground reaction peak is also decreased that means that the body is not only sustaining more force from wearing the brace, but it also cannot effectively absorb force (McCaw & Cerullo, 1999; Rieman et al., 2002). Prior research further suggests that decreasing the time to absorb impact force is an important factor that may over-stress the musculoskeletal system and increase injury risk (Riemann et al., 2002; Simpson et al., 2013). For example, Rieman et al. (2002) had participants perform a drop landing before and after a 20-minute bout of jogging in both an ankle-braced and non-braced condition. It was found that there was a decrease in dorsiflexion, plantar flexion, and maximum angular velocity. Decreased dorsiflexion in particular is an important indicator for whether there will be increased force transferred to the knee and hip.

Ankle Bracing and Proximal Joint Force Transfer

During impact, the body absorbs force distally at the ankle and then transfers proximally to the knee and then the hip (Saunders, 1993). Any residual force is absorbed through bone, cartilage, and surrounding soft tissue. If force absorption at the ankle is limited, then it must be transferred to the knee and hip (Vanesky et al., 2006). During ankle bracing, it is thought that if force cannot be properly absorbed through the ankle then the knee and hip must take up that force, creating a higher injury potential at those joints (Vanesky et al., 2006).

Evidence regarding the effect of ankle bracing on more proximal joint mechanics is unclear. Santos et al. (2004) found that during an open trunk rotation task, in which participants rotated to catch a tossed ball, hip internal rotation and ankle internal rotation decreased in response to ankle bracing. During a closed trunk rotation task, in which participants rotated their trunk to a fixed end point, ankle bracing resulted in decreased hip rotation and increased knee rotation. However, during a drop-landing task, it was found that ankle bracing did not affect the varus and valgus torque at the knee (Vanesky et al., 2006). Similarly, during a single-leg drop landing, it was found that there was no significant change in the amount of kinetic energy absorbed by the ankle, knee or hip in response to wearing a hinged-brace or boot brace condition (Gardner, 2012). While it remains unclear whether ankle bracing influences knee and hip joint mechanics, it is also important to note that ankle bracing via taping was not tested in any of these prior studies (Gardner, 2012; Santos et al., 2004; Vanesky et al., 2006). Ankle taping is a more restrictive type of bracing and may have a greater effect on proximal joint mechanics.

Chronic ankle instability occurs when stabilizing muscles of the ankle are weakened, usually due to injury. Long-term use of ankle braces can weaken surrounding musculature due to the decrease in muscle activation (Doherty et al., 2016). In those with chronic ankle instability, there was more preparatory flexion of the hip before landing, decreasing the amount of flexion of the hip after landing. This motion is the primary force absorbing movement of the hip during landing. It was found that the hip is critical in "arresting the downward velocity of the body and preventing collapse of the lower extremity" (Doherty et al., 2016). It is unclear how mechanics are changed at the hip when braced at the ankle.

Purpose of the Study

The purpose of this study is to investigate the effects of ankle bracing on kinematics and kinetics of the knee, hip and lumbro-sacral joints. Evidence as to whether ankle braces affect knee, hip and lumbo-sacral kinematics and kinetics has been inconclusive. The hip is extremely important in producing power and stability of the lower extremity and so altering mechanics at the hip during jump landing may result in a higher risk of injury. It is important for athletes and athletic trainers to understand the effects of bracing the ankle on the mechanics of more proximal joints, and at this point, those consequences are not fully understood.

Hypothesis

Based on evidence that the ankle ROM is restricted and the reduced ability of the ankle to absorb force through its musculature and surrounding soft tissue, it is believed that the alternative hypothesis will be accepted. Therefore, it is hypothesized that ankle bracing will result in an increase in knee, hip, and lumbosacral peak flexion and peak flexion moments when landing from a vertical jump.

METHODS

Participants

This study consisted of 6 male and 6 female intercollegiate basketball athletes ages 18-25 years. All subjects were volunteers. All subjects met the criteria of not having any injuries within the last six months that could alter performance on a vertical jump or depth drop. Injuries pertained to, but were not limited to: any musculoskeletal injury still in the healing process, restricted ankle ROM, improperly healed injuries of the ankle, knee, or hip, bilateral imbalance of strength, or any other recent injury to the lower extremity that may have altered normal jumping mechanics. A health questionnaire was utilized to determine participation in this study (Appendix B). All participants wore spandex and a tight-fitting shirt. Participants did not wear shoes or socks during the jump trials. All participants gave informed consent before participating in this study. This study was approved by the Institutional Review Board for Human Subjects Research at Humboldt State University.

Research Design

This study was a true experimental design with randomized conditions. This study analyzed the effect of two different types of prophylactic ankle bracing on kinematics and kinetics of the knee, hip, and low back during a vertical jump landing and a depth drop. The study was counterbalanced for the vertical jump and depth drop variable. Half of the subjects performed the vertical jump first and the depth drop second. The other half of the subjects performed the depth drop first and the vertical jump second.

Procedures

The data collection occurred during two days. Day 1 consisted of an orientation in which subjects filled out the medical questionnaire and gave informed consent for participation. Anthropometric measurements were also gathered. On this day, each subject performed three maximal vertical jumps in order to obtain separate average maximal jump height for men and women. Each average was used to calculate 75% of the maximal jump; the height used in the depth drop trials. Jump height was measured in inches using a “Vertec” measuring device. The following day included collecting data on jump and drop landings. Each subject did one warm-up jump and then two maximal vertical jump attempts. Each subject had marker balls placed on lower limbs and trunk in order to analyze hip and knee flexion through the Vicon three-dimensional motion capture system. Subjects landed on force plates to obtain information on joint moments. When landing from a vertical jump, each participant was instructed to land with each foot on separate adjacent force plates in order to obtain separate measurements for each leg. If subjects failed to follow this direction, vertical jumps/depth drops were repeated until two successful trials were acquired, without exceeding a maximum of five jumps. This was done to ensure that the tape did not break down during the jumping portion.

After the orientation day, the next day scheduled with the participant was for data collection in each bracing condition including the non-braced condition. Each bracing condition was randomized for each participant. A Certified Athletic Trainer applied all prophylactic supports bilaterally. The method of application was a Closed Gibney technique. This technique contains both figure eights and heel locks and is the most common method for preventing and treating a sprained ankle.

Dynamic warm-ups were done before beginning collection and consisted of heel/toe walking, bodyweight squats, lunges, straight leg kicks, high skips, and backpedaling. Functional exercise consisted of a 15-minute exercise regimen, utilizing a modified Illinois Agility Test (See Appendix C). The subjects ran at a sub-maximal pace for 7.5 minutes in one direction, then 7.5 minutes in the other direction. Pace was consistent for each participant during the exercise and was maintained constantly at a rate of perceived exertion (RPE) of 3 which is defined as moderate exercise (See Appendix D). The subject's RPE level was monitored at six separate times to ensure that it remained at a 3. The six recordings took place during: 1. The first lap 2. The two-minute mark 3. The five-minute, thirty-second mark 4. The seven-minute, thirty-second mark 5. The nine-minute, thirty-second mark 6. The thirteen-minute mark. The participant then slowed down or sped up to remain at a 3. If the participant needed to take a break during the functional exercise portion, they were granted time to do so.

Methods for each condition were as follows:

1. Application of supportive device (cloth tape, self-adherent tape, or brace)
2. Application of skin markers (only foot marker balls will be removed between trials)
3. Perform first jump trials (Pre-exercise data)

4. Perform functional exercise
5. Re-application of skin markers
6. Perform second jump trials (Post-exercise data)

Measurements/Instrumentation

All lower body kinematics were measured using 3D high-speed digital motion capture (120 field/s, T-10 Vicon, Centennial, CO) and reflective markers were placed on the lower extremities and the torso using a cluster model. We digitized the markers and filtered the position data using a fourth-order zero-lag Butterworth filter with a cutoff frequency of 6 Hz (Winter 1999). From the position data, we calculated lower limb kinematics in the sagittal and frontal planes for one of the successful jumping trials. If there were multiple, successful jumping trials, the jumping trial that subjectively showed the higher vertical was chosen to analyze. For the drop trails, the first successful trial was chosen to analyze.

We measured center of mass motion by utilizing vertical ground reaction forces for each jump trial taken from the force platforms (Model OR6-7, AMTI, Watertown, Maine). Force data was collected with a sampling rate of 1000 Hz and low-pass filtered the data using a fourth-order zero-lag Butterworth filter with a cutoff frequency of 20 Hz. We used the filtered vertical ground reaction force data to calculate the acceleration of the center of mass in each direction. We then double integrated the acceleration data with respect to time for each jump and determined the instantaneous center of mass vertical velocity and displacement during the landing phase of the jump; from initial ground contact until the center of mass has reached the lowest point to the ground (Blickhan & Full, 1993; Linthorne, 2001; Bot & Van Mechelen, 1999). Peak hip and knee flexion angles were measured in degrees using the Vicon three-dimensional motion capture software. Peak hip, knee, and lumbosacral moment measurements were quantified using lower body kinematic data and the two separate force plate measurements. We used ground reaction force, lower limb and torso kinematic measurements and inverse dynamic equations to calculate moments of the knees, hips, and lumbosacral joint during the landing phase of each jump. We then used these values to calculate the means of each variable for each trials of each jump condition (vertical jump and depth drop).

Independent Variables

The independent variables for this study were the three taping conditions: a control (no tape), adhesive tape (Perform Plus" from Mueller with pre-wrap), and self-adhesive tape ("Power Tape" from Andover with a Powerflex underwrapping). The other independent variable was exercise (pre- or post-exercise).

Dependent Variables

Dependent variables for this study included peak knee flexion (deg), peak hip flexion (deg), peak hip moment (Nm/kgm), peak knee moment (Nm/kgm), peak hip moment (Nm/kgm), and peak lumbosacral moment (Nm/kgm). All peak moment measurements were normalized to body mass and height.

Statistical Analysis

IBM SPSS 25 (version 25.0; Chicago, IL, USA) was used to run the statistical analysis to identify any changes in the dependent variables. The independent variables were the three taping conditions (none, adherent, self-adherent), and exercise (pre and post). The five dependent variables included peak knee flexion, peak hip flexion, peak knee moment, peak hip moment, and peak lumbosacral moment. A two-way MANOVA was performed with an apha level of .05 to determine significance. All data is reported as a mean ± standard error of the mean.

Operational Definitions

Maximum vertical Jump: A jump where an individual tries to raise their center of mass vertically as high as possible when jump off of two feet, landing on two feet, and starting from a standstill.

Average Maximum vertical Jump height: maximum vertical jump height averaged across all subjects of the same gender.

Depth drop jump: An individual stepping off of a fixed height set at 75% the average gender-specific maximum vertical jump, landing on two feet.

Landing Phase: The last phase of a jump from time of foot contact to the time when the center of mass is at its lowest vertical height.

Plantarflexion: Flexion of the ankle joint so that the toes and plantar surface of the foot rotates downwards.

Dorsiflexion: Flexion of the ankle joint so that the toes and plantar surface of the foot rotates upwards.

Peak lumbosacral moment: The peak lumbosacral moment across the entire landing phase of a jump.

Assumptions

1. The subjects gave their best effort during all vertical jump attempts.
2. The motion analysis software is sensitive enough to measure sagittal plane knee, hip and lumbro-sacral joint motion.
3. The force plates are sensitive enough to measure individual limb GRF measurements.
4. All tape applications were equal in technique and tightness for all participants.

Limitations

1. Participants ability to land on two separate force plates while maintaining a natural jump and landing motion.
2. Participants maximum vertical jump heights may be different heights due to skill and strength differences
3. The consistency of the ankle taping and bracing applications may differ among subjects. If the adhesive or self-adherent tape were not consistently applied for all participants, differences in findings could occur.

Delimitations

1. This study only included participants who did not have any previous injury that affected their vertical jump or landing capabilities.
2. This study only tested the use of two specific brands of tape.
3. The functional exercises administered in this study did not include actual game play. Accurate depictions of game/practice conditions may not have been fully achieved.
4. Only collegiate male and female basketball players will be used in this study. A larger sample size consisting of more sports may yield different results.

RESULTS

Subject Characteristics

After screening a total of 24 athletes, 12 athletes volunteered and met the requirements detailed in the Health Questionnaire (Appendix A). Descriptive information of the subjects is reported below (Table 1).

Table 1: Descriptive Statistics +/- SD

Gender	n	Age (yrs)	Height (M)	Weight (Kg)	Jump Height (Inches)	75% Jump Height (Inches)
Male	6	21.3 ± 1.9	1.9 ± .15	90.5 ± 16.7	32.9 ± 3.0	24.7
Female	6	21.5 ± 2.1	1.7 ± .15	65.1 ± 16.4	20.2 ± 3.4	15.2

Kinematics and Kinetics

Analysis of ankle bracing pre- and post-exercise on lower extremity kinematics and kinetics through a two-way MANOVA yielded results that were not significant for any of the variables, including their interaction effect. Specifically there was no effect of the taping conditions (control, adhesive, self-adhesive) on peak knee flexion ($p=.683$, partial $\eta^2=.005$), peak hip flexion ($p=.396$, partial $\eta^2=.013$), peak knee moment ($p=.502$, partial $\eta^2=.010$), peak hip moment ($p=.679$, partial $\eta^2=.006$), and peak lumbosacral moment ($p=.299$, $\eta^2=.017$). There was no effect of exercise (pre vs. post) on peak knee flexion ($p=.207$, partial $\eta^2=.012$), peak hip flexion ($p=.240$, partial $\eta^2=.010$), peak knee moment ($p=.742$, partial $\eta^2=.001$), peak hip moment ($p=.737$, partial $\eta^2=.001$), and peak lumbosacral moment (p=.447, partial η^2=.004). There was no interaction effect between tape and pre and post exercise for peak knee flexion (p=.538, partial η^2=.009), peak hip flexion (p=.381, partial η^2=.014), peak knee moment (p=.830, partial η^2=.003), peak hip moment (p=.666, partial η^2=.006), and peak lumbosacral moment (p=.239, partial η^2=.020).

Table 2: Average Peak Hip Flexion Angle +/- SEM (Degrees)

Tape Condition	Jump *Pre-Ex.*	Jump Post-Ex.	Drop Pre-Ex.	Drop Post-Ex.
Control	36.36 ± 4.53	38.46 ± 7.23	35.75 ± 3.51	38.41 ± 5.30
Adhesive	42.92 ± 5.29	37.60 ± 5.31	43.21 ± 3.58	36.09 ± 4.22
Self-Adhesive	31.06 ± 6.40	26.63 ± 6.33	45.86 ± 3.98	36.25 ± 5.96

Table 3: Average Peak Knee Flexion Angle +/- SEM (Degrees)

Tape Condition	Jump Pre-Ex.	Jump Post-Ex.	Drop Pre-Ex.	Drop Post-Ex.
Control	66.49 ± 3.50	64.37 ± 4.11	62.86 ± 4.20	63.46 ± 5.39
Adhesive	63.08 ± 4.38	64.45 ± 4.28	67.35 ± 2.95	62.13 ± 3.46
Self-Adhesive	57.15 ± 7.50	54.67 ± 5.17	74.07 ± 2.86	36.25 ± 5.96

Table 4: Average Peak Knee Flexion Moment +/- SEM (Nm/kgm)

Tape Condition	Jump Pre-Ex.	Jump Post-Ex.	Drop Pre-Ex.	Drop Post-Ex.
Control	1.22 ± 0.10	1.26 ± 0.10	0.90± 0.09	0.92 ± 0.09
Adhesive	1.02 ± 0.07	1.22 ± 0.11	1.08 ± 0.05	1.01 ± 0.10
Self-Adhesive	0.94 ± 0.15	1.06 ± 0.12	1.09 ± 0.07	0.91 ± 0.14

Table 5: Average Peak Hip Flexion Moment +/- SEM (Nm/kgm)

Tape Condition	Jump Pre-Ex.	Jump Post-Ex.	Drop Pre-Ex.	Drop Post-Ex.
Control	1.07 ± 0.18	1.06 ± 0.15	1.11 ± 0.19	1.08 ± 0.16
Adhesive	0.97 ± 0.14	1.17 ± 0.13	1.34 ± 0.20	1.28 ± 0.19
Self-Adhesive	1.12 ± 0.21	1.11 ± 0.19	1.34 ± 0.17	1.04 ± 0.19

Table 6: Average Peak Lumbosacral Flexion Moment +/- SEM (Nm/kgm)

Tape Condition	Jump Pre-Ex.	Jump Post-Ex.	Drop Pre-Ex.	Drop Post-Ex.
Control	0.94 ± 0.15	1.25 ± 0.13	1.13 ± 0.06	1.22 ± 0.10
Adhesive	0.77 ± 0.16	1.03 ± 0.12	1.27 ± 0.07	1.16 ± 0.14
Self-Adhesive	0.89 ± 0.18	0.80 ± 0.14	1.21 ± 0.08	1.08 ± 0.12

DISCUSSION AND CONCLUSION

Discussion

This study explored the effects of two different methods of ankle taping (adhesive and self-adhesive) on selected lower extremity kinematics and kinetics during vertical jump and a depth drop landing before and after participation in exercise. The results of this study showed no effect of taping on knee flexion, hip flexion, knee moment, hip moment, and lumbosacral moment. This reflects in contrast to the initial hypothesis, the moment for the more proximal joints did not increase as a result of ankle taping.

The purpose of ankle taping is to reduce the range of motion of the ankle and decrease the occurrence of injuries such as the lateral ankle sprain (Greene et al., 2014; McCaw & Cerullo, 1999; Simpson et al., 2013). It has been thought that if there is a significant reduction in ROM then there would be a significant increase in the moments felt at the more proximal joints of the knee, hip, and low back (McCaw & Cerullo, 1999; Rieman et al., 2002). This hypothesized increase in moments at these joints could potentially increase an athlete’s likelihood for sustaining injury (Rieman et al., 2002). This increase in moment, however, was not seen in this study, and instead there was no difference between tape conditions. This lack of change is likely related to the lack of changes seen in lower body joint ROM. In a study done by McCaw & Cerrullo (1999), it was shown that dorsiflexion ROM decreased by five degrees when the ankle was taped. Although this difference may be statistically significant, the difference may not be physiologically or mechanically significance (Ellis & Steyn, 2003). It has also been shown that there was no change in ground reaction forces when wearing ankle tape (DiStefano et al., 2008). The lack of change in ground reaction forces, combined with a minimal change in ROM, means that the body does may not need to compensate for a reduction of force absorption at the ankle through an increase in more proximal joint moments (Mccaw & Cerullo, 1999; Riemann et al., 2002).

In this study, participants were told to jump as high as they could while landing both feet at the same time on two different force plates. This prescribed method of landing, likely negatively influenced the subjects' ability to achieve a maximal jump height. The instructions of jumping style likely reduced their maximal vertical jump and therefore decreased the overall moment at each joint. However, one limitation of this study is that we did not measure vertical jump height for the experimental trials. If subjects were able to jump higher, they may have better maximized the peak joint moments, and thus we might have observed a greater difference between taping conditions. In a study done by McNair et al. (2000), it was shown that instruction and cues on maximal jump led to significant decreases in maximal vertical ground reaction forces. Instruction in the present study may have led to an overall decrease in maximal vertical ground reaction forces, which could be a major contributing factor to the lack of differences in joint moments due to taping.

The vertical jump and depth drop are movements that primarily occur in the sagittal (fore-aft) plane. It has been shown in previous studies that utilized this type of task that landing forces do not increase (DiStefano et al., 2008; Mason-Mackay et al., 2016; West, Ng & Cambell, 2014). The ankle brace is meant to prevent inversion injuries, and this motion occurs in the frontal plane (Pederson et al., 1997). Had the subjects participated in a movement that incorporated a frontal plane task such as a cutting maneuver, it is possible that there would have been differences in the moments at the more proximal joints of the hip and knee (West, Ng & Campbell, 2014). It was found in a previous study in which subjects landed on a slant board that there was an increase in knee varus-valgus moment and knee internal rotation moment (Vanesky et al., 2006). This shows that there is potential to see significant changes in proximal joint moments in tasks that involve motions beyond the sagittal plane. This is also more realistic movement that better mimics competition. Future studies seeking to investigate the effect of ankle taping should focus on having subjects jump maximally in a way that mimics more natural jumping technique. Moreover, future studies interested in testing the interaction effect of exercise and taping on jump landing mechanics should use exercises that better mimic the more lateral motions associated with natural game play.

One of the largest considerations in this study was the potential for ankle braces to increase the likelihood for injury. It has been shown in previous studies that there is a decrease in time to peak impact when landing from a jump while wearing ankle braces (Riemann et al., 2002). Over many repetitions, this might increase the amount of external force experienced by the body (Riemann et al., 2002). Thus, one limitation in the present study is that we measure instantaneous force during each jump and did not look at total force experienced over several jumps. It has been suggested, however, that even during volleyball specific tasks that included running, jumping, and lateral tasks, that there was no change in knee kinematics or kinetics during jump landing (West, Ng & Campbell, 2014). Even in more long-term outcomes including wearing an ankle brace for 8 weeks during all recreational activity, there was still no observed change of ankle kinematics and kinetics during a jump landing task (DiStefano et al., 2008).

Future Research

The results of this study showed no effect on lower extremity kinetics and kinematics, however, there is still more research that should be conducted to understand this topic. This study had a statistically sufficient but nonetheless small sample size of only 12 participants. This study was also done with a mixture of athletes that either wore ankle bracing during all activity or only during competition. The covariant of familiarity of use with the ankle brace could potentially have had an effect on our overall results. It could be possible that those who are used to wearing ankle bracing, may be conditioned to their use and therefore less susceptible to changes when wearing them. In order to investigate this further, a larger sample size should be utilized with a better understanding of how often each athlete has worn ankle bracing prior to the study. Other research should focus on an experimental design that utilizes a more maximal vertical jump where participants are only instructed to jump as high as they can and allowed to land asymmetrically. This could create a larger kinetic and kinematic disparity between the conditions, as it would truly maximize the potential to understand the differences (Lai & Lee, 2015). In totality, there needs to be a focus on the long-term effects of wearing ankle braces in a population that has never worn them. A more longitudinal design can give a better understanding to the actual potential for ankle bracing to increase the potential for injury at other joints including the knee and hip. Finally, future research should focus on the changes that occur in muscle activation. An understanding of how muscles may be over-stimulated or under-stimulated could give potential for understanding where overuse and fatigue related injury may or may not occur in the body.

Conclusion

In conclusion, wearing ankle braces does not increase moments at the more proximal joints of the knee and hip and does not have an effect on selected lower extremity kinematics. At this time it cannot be definitively stated whether wearing adhesive or self-adhesive ankle tape has an effect on jump landing mechanics. Wearing ankle bracing has not been shown to increase the propensity for injury by increasing forces through the body. When landing from a jump, it is probable that there is no physiological effect to the rest of the lower body that would make it more likely to sustain injury. This topic should be further investigated to better understand whether athletes that are required to wear ankle bracing are at an increased risk to harm other areas of the body.

Author Contributions

Conceived and designed the experiments: Chris Gregoire, Justus Ortega, Shannon Childs

Performed the experiments: Riann Thayer, Chris Gregoire, Stephanie Chuml, Jazz Lewis, Ryan Matteri

Analyzed the data; Riann Thayer, Chris Gregoire, Justus Ortega

Wrote the paper: Riann Thayer, Justus Ortega

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APPENDIX A

The Effects of Self-Adherent Taping on Peak Inversion Angle and Angular Torque Upon Landing During a Vertical Jump and a Depth Drop

Principal Investigator: Chris Gregoire, B.S.

(Approval Date:)

PARTICIPANT INFORMED CONSENT FORM

Please read the following material that explains this research study. Signing this form will indicate that you have been informed about the study and that you want to participate. We want you to understand what are you are being asked to do and what risks and benefits are associated with the study. This should help you decide whether or not you want to participate in this study.

You are being asked to participate in a research project conducted by Chris Gregoire under the supervision of Justus Ortega, Ph.D., Department of Kinesiology and Recreation Administration, 1 Harpst St., Arcata, CA, 95521. **Dr. Justus Ortega may be reached at (707) 826-4274 or jdo1@humboldt.edu to answer any questions or concerns.**

Project Description:

The purpose of this study is to examine the effectiveness of self-adherent tape in controlling peak inversion motion and angular torque compared to traditional cloth tape. Athletic tape is a commonly used application for helping prevent and treat ankle injuries. Some research gives credibility to the method of stabilization, however, there is also a lot of research questioning its reliability and effectiveness. Self-adherent tape may prove to be a better means of stabilizing the ankle against inversion. However, the effectiveness of self-adherent tape in reducing inversion motion and torque during landing remains unclear; especially in comparison to the traditional ankle stabilization modalities of traditional taping. You are being asked to be in this study because you are 18-25 years of age and in good health. Participation in this study is entirely your choice.

Procedure:

If you agree to take part in this study, you will be asked to come to the laboratory for three experimental sessions. There is no monetary compensation for participation in this study. All experimental sessions will take place in the HSU Biomechanics Lab and the Lumberjack Arena.

Orientation and Preliminary Jump Session (30 minutes)

- We will explain the study and what we will ask you to do.

- You will read the informed consent.
- We will answers any questions you may have.
- You will sign the informed consent form, if you agree to participate in the study.
- You will complete a medical history questionnaire
- You will perform 3 maximal vertical jumps as a base measurement
- Your inversion range of motion will be taken

Jump Sessions (about one hour thirty minutes)

- You will perform a set dynamic warm-up series
- We will apply an external ankle prophylactic (either self-adherent tape, cloth tape, or none at all)
- We will apply reflective ball markers onto your lower body
- You will perform 3 maximal vertical jumps and 3 depth drops
- You will perform a 15 minute bout of jogging in a set pattern
- We will reapply reflective ball markers
- You will perform 3 maximal vertical jumps and 3 depth drops once again

Participation in this study should take approximately five hours and five minutes total time. The total time commitment is broken up as follows; orientation (30 minutes), and experimental trials (1 hour and 30 minutes per day [3 days]).

A maximum of 30 participants will be invited to participate in this research study.

Risks and Discomforts:

There are some potential risks if you take part in this study. During both the vertical jumping tests, the depth drops, and the jogging, there is a small risk that you may injure yourself. In the case that you become injured or feel uncomfortable continuing, the test will be stopped. There is some risk of falling during the jumping and jogging sessions as well. There is also risk of musculoskeletal and/or ligamentous injury due to the explosive movements during the vertical jump test. During the experimental sessions there is a small risk that you might experience skin irritation when we remove adhesive reflective markers. However, we will be using hypoallergenic adhesive to minimize this risk. Moreover, the members of our research team that will be conducting this experiment are all CPR and first aid certified and will provide constant supervision as an additional safety precaution. Aside from these risks, none of the other procedures should cause you discomfort or injury.

Benefits:

The benefits to the subjects for participating in this study include: (a) knowledge of the new preventative and treatment tape options, (b) light exercise during exercise regimen.

Subject Payment:

You will not be paid for participation in this research study.

If you feel that you have been harmed while participating in this study, you should inform the faculty supervisor, Dr. Justus Ortega, (707) 826-4274 immediately. If you are injured, Humboldt State University will not be able to pay for your medical care. State law may limit Humboldt State University's legal responsibility if an injury happens because of this study.

Study Withdrawal:

You have the right to withdraw your consent or stop participating at any time. You have the right to refuse to answer any question(s) or participate in any procedure for any reason.

Confidentiality:

We will make every effort to maintain the privacy of your data. From the beginning of your participation, you will be given a unique identity code. This code will be used instead of your name for all documentation of your participation. We will keep your individual data and results confidential including computer files, paper files, and any personal information. In written or oral presentations of the results of this research, your identity and individual information will be kept confidential. After the project is complete, the materials associated with the project, including computer files, paper files, digital video files, and personal information will be secured in a locked cabinet in a locked office under the supervision of Dr. Justus Ortega for five years in case there is a need for future verification or reanalysis of the data. Upon completion of this informed consent form, you will receive a signed copy of the consent form.

Other than the research team, only regulatory agencies, such as the Humboldt State University Committee for the Protection of Human Subjects in Research may see your individual data as a part of routine audits.

Invitation for Questions:

If you have questions about this study, you should ask the researcher before you sign this consent form. **You may also contact Chris Gregoire, the Primary Investigator to answer any questions or concerns regarding the study at cmg454@humboldt.edu or (916) 524-6176.**

If you have any concerns with this study or questions about your rights as a participant, contact the Institutional Review Board for the Protection of Human Subjects at irb@humboldt.edu or (707) 826-5165.

Authorization:

I have read this paper about this study or it was read to me. I know the possible risks and benefits. I know that being in this study is voluntary. I know that I can withdraw at any time. I have received, on the date signed, a copy of this document containing 4 pages. I understand that the researcher will answer any questions that I may have concerning the investigation or procedures at any time. I also understand that my participation in this study is entirely voluntary and that I may decline to enter this study or may withdraw from it at any time without any penalty. I understand that the investigator may terminate my participation in the study at any time.

Name of Participant (printed) ____

Signature of Participant ___________________________ Date ______________.
(Also initial all previous pages of the consent form.)

For IRB Use Only

APPENDIX B

Medical History
The personal health history is designed to assist the study by maintaining a safe atmosphere to each participant. Please write neatly and fill out form in ink only. Please answer truthfully, completely and provide dates and details to the best of your knowledge for each yes response. The information you provide is confidential. Prior to the start of study your medical history form will be revealed to make sure you are safe to take part in the study. If yes responses are not adequately explained, further interviewing will be necessary before medical clearance is granted.

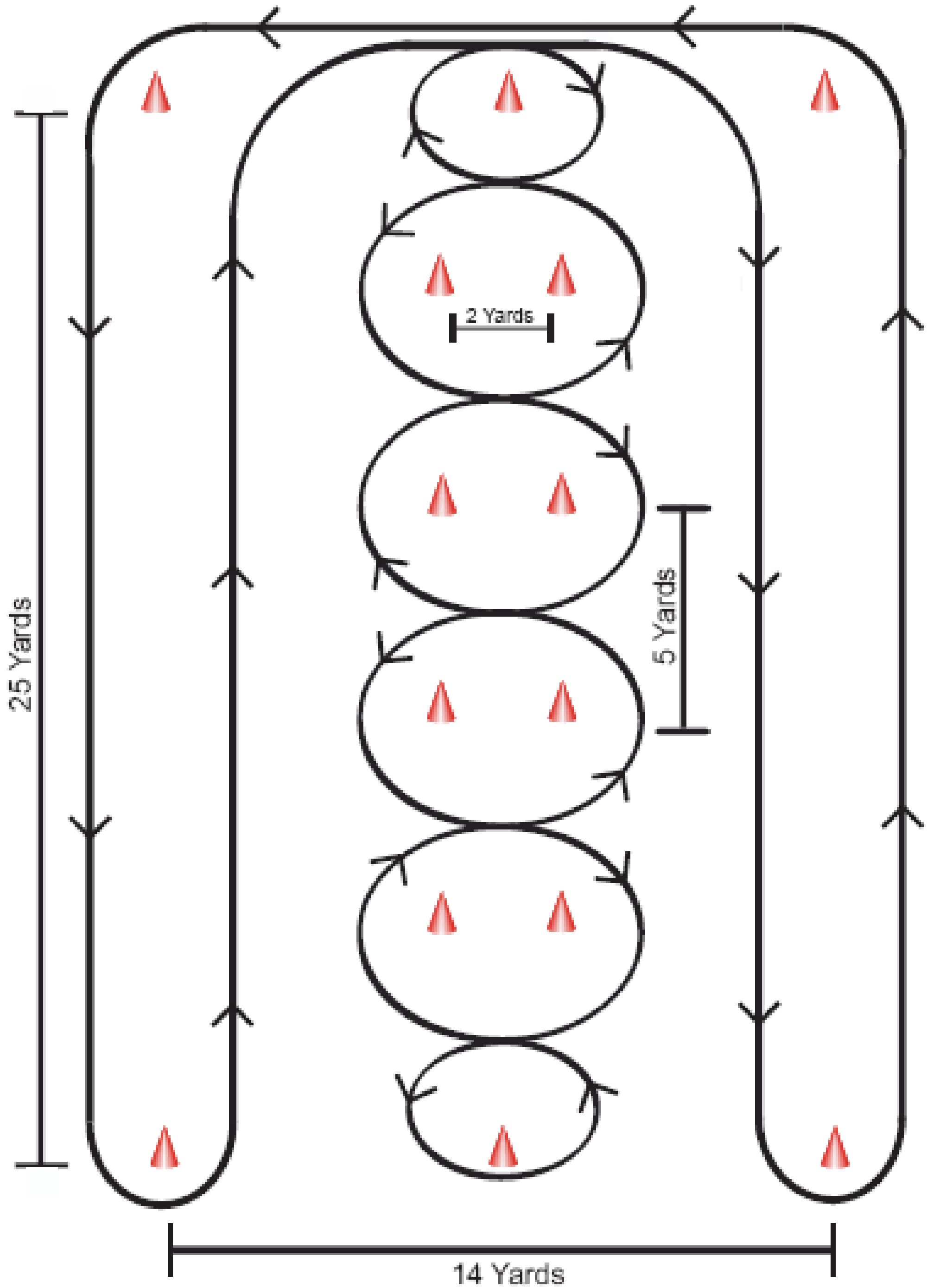
Please check the appropriate response for each question.

Item #:	**In the past 6 months, have you ever had or do you currently have:**	**Response:**	**Details (specific information, dates, brief explanations):**
1	Concussion/head injury?	Yes No	Date of most recent? Currently have symptoms? Yes No
2	Fractured/broken bone?	Yes No	If yes, when? If yes, what body part?
3	Injury to neck?	Yes No	When? Diagnosis:
4	Injury to shoulder?	Yes No	When? right left both Diagnosis:
5	Injury to elbow/wrist/hand?	Yes No	When? right left both Diagnosis:
6	Injury to back/spine?	Yes No	When? Diagnosis:
7	Injury to abdomen, chest or ribs?	Yes No	When? Diagnosis:
8	Injury to hip/pelvis?	Yes No	When? right left both Diagnosis:

Item #:	**In the past 6 months, have you ever had or do you currently have:**	**Response:**	**Details (specific information, dates, brief explanations):**
9	Injury to knee?	Yes□No	When? right left both
10	Injury to ankle/foot/leg?	Yes□No	When? Right, Left, Both Diagnosis:
11	Injury to face/eye/nose?	Yes□No	When? Diagnosis:
12	Stress Fractures?	Yes□No	Body part:
14	Recent surgeries?	Yes□No	If yes, please explain:
15	Do you currently have an unhealed injury?	Yes□No	If yes, please explain:
16	Any other injuries, illnesses, or other health related issues not listed?	Yes□No	If yes, please explain:

Additional notes (please reference with item #, use back of page if necessary):

APPENDIX C: MODIFIED ILLINOIS AGILITY TEST



APPENDIX D: RATE OF PERCEIVED EXERTION SCALE

HOW HARD IS THE ACTIVITY?

0	Nothing at all
0.5	Just noticeable
1	Very light
2	Light
3	Moderate
4	Somewhat heavy
5	Heavy
6	
7	Very heavy
8	
9	
10	Very, very heavy
* *	Maximal

TABLES

Table 1: Descriptive Statistics +/- SD

Gender	n	Age (yrs)	Height (M)	Weight (Kg)	Jump Height (Inches)	75% Jump Height (Inches)
Male	6	21.3 ± 1.9	1.9 ± .15	90.5 ± 16.7	32.9 ± 3.0	24.7
Female	6	21.5 ± 2.1	1.7 ± .15	65.1 ± 16.4	20.2 ± 3.4	15.2

Table 2: Average Peak Hip Flexion Angle +/- SEM (Degrees)

Tape Condition	Jump *Pre-Ex.*	Jump Post-Ex.	Drop Pre-Ex.	Drop Post-Ex.
Control	36.36 ± 4.53	38.46 ± 7.23	35.75 ± 3.51	38.41 ± 5.30
Adhesive	42.92 ± 5.29	37.60 ± 5.31	43.21 ± 3.58	36.09 ± 4.22
Self-Adhesive	31.06 ± 6.40	26.63 ± 6.33	45.86 ± 3.98	36.25 ± 5.96

Table 3: Average Peak Knee Flexion Angle +/- SEM (Degrees)

Tape Condition	Jump Pre-Ex.	Jump Post-Ex.	Drop Pre-Ex.	Drop Post-Ex.
Control	66.49 ± 3.50	64.37 ± 4.11	62.86 ± 4.20	63.46 ± 5.39
Adhesive	63.08 ± 4.38	64.45 ± 4.28	67.35 ± 2.95	62.13 ± 3.46
Self-Adhesive	57.15 ± 7.50	54.67 ± 5.17	74.07 ± 2.86	36.25 ± 5.96

Table 4: Average Peak Knee Flexion Moment +/- SEM (Nm/kgm)

Tape Condition	Jump Pre-Ex.	Jump Post-Ex.	Drop Pre-Ex.	Drop Post-Ex.
Control	1.22 ± 0.10	1.26 ± 0.10	0.90± 0.09	0.92 ± 0.09
Adhesive	1.02 ± 0.07	1.22 ± 0.11	1.08 ± 0.05	1.01 ± 0.10
Self-Adhesive	0.94 ± 0.15	1.06 ± 0.12	1.09 ± 0.07	0.91 ± 0.14

Table 5: Average Peak Hip Flexion Moment +/- SEM (Nm/kgm)

Tape Condition	Jump Pre-Ex.	Jump Post-Ex.	Drop Pre-Ex.	Drop Post-Ex.
Control	1.07 ± 0.18	1.06 ± 0.15	1.11 ± 0.19	1.08 ± 0.16
Adhesive	0.97 ± 0.14	1.17 ± 0.13	1.34 ± 0.20	1.28 ± 0.19
Self-Adhesive	1.12 ± 0.21	1.11 ± 0.19	1.34 ± 0.17	1.04 ± 0.19

Table 6: Average Peak Lumbosacral Flexion Moment +/- SEM (Nm/kgm)

Tape Condition	Jump Pre-Ex.	Jump Post-Ex.	Drop Pre-Ex.	Drop Post-Ex.
Control	0.94 ± 0.15	1.25 ± 0.13	1.13 ± 0.06	1.22 ± 0.10
Adhesive	0.77 ± 0.16	1.03 ± 0.12	1.27 ± 0.07	1.16 ± 0.14
Self-Adhesive	0.89 ± 0.18	0.80 ± 0.14	1.21 ± 0.08	1.08 ± 0.12