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Original Research Article

The Effects of Kinesio Tape on Range of Motion, Power Output, and Strength in Female Collegiate Club Athletes

Lauren T. Flood[1], Rachel L. Hassler[1], Jessica L. Sykora[1]
[1]Department of Kinesiology, University of Wisconsin – Eau Claire, Eau Claire, WI, USA

Abstract

Purpose: In athletics, lower extremity muscle strains comprise a large percentage of all injuries recorded. To date, no conclusive research exists in determining the most successful and effective preventative technique through improving strength and range of motion (ROM). The purpose of this study; therefore, was to determine the effectiveness of Kinesio Tape (KT) and its sustainability of the anecdotally proposed benefits of increased muscular strength, elasticity, and power output amongst female collegiate club athletes. **Methods:** Thirteen female college students (ages 18-22 years) participated in this study. All participants were randomly assigned to either the hamstrings or quadriceps treatment groups. Each group underwent identical treatment protocol during each of the three measurement sessions: baseline, immediately post-application, and 3-days post-application. During the second session, the KT was applied bilaterally to the participant according to their randomly assigned treatment group. Each treatment session was conducted and administered with 72 hours between sessions. Bilateral ROM, power output, and bilateral isokinetic strength were measured using the following assessment techniques: two-arm manual goniometer, Vertec, and the HumacNorm isokinetic machine, respectively. **Results:** Isokinetic strength and ROM were statistically analyzed according to treatment group, as compared to an overall result. A one-way repeated measures analysis of variance (RM ANOVA) revealed no time effect on right and left limb isokinetic strength at 60 and 180 degrees per second for both hamstrings and quadriceps groups ($p > .05$). With respect to ROM, one-way RM ANOVA showed significant time effects on active hip flexion for hamstrings group and active knee flexion for quadriceps group bilaterally. Paired-samples t-tests revealed a significant increase in right and left hip flexion from baseline to 3-day post application, $t(5)=3.54$, $p=.017$ and $t(5)=6.96$, $p=.001$, respectively, as well as from baseline to immediately post-application, $t(5)=-3.97$, $p=.01$ and $t(5)=-2.64$, $p=.046$, respectively. Amongst the quadriceps group, a significant increase was found in the right and left active knee flexion from immediately post-application to 3-days post-application, $t(6)=-3.47$, $p=.013$ and $t(6)=-3.11$, $p=.021$. A two-way repeated measures ANOVA revealed a significant time effect. Paired-samples t-tests indicated significant improvement in power output performance from baseline (14.94±1.68 inches) to 3-day post-application (16.13±1.77 inches), $t(12)=-4.21$, $p=.001$. There was also significance between immediately post-application (15.34±2.03 inches) and 3-day post-application, $t(12)=-2.37$, $p=.036$. The participants' perceived overall performance (as measured by Global Rating of Change Scale; range -7 to 7) was 2.31±1.75, indicating a slight improvement in their subjective rating. **Conclusion:** The current study showed that the use of KT could improve athletic performance where increased hip and knee ROM and power are of importance. Further research should focus on the impacts of improved muscle elasticity and lower extremity power on injury prevention.

Key Words: Kinesiology Tape, Orthopedic Tape, Vertical Jump, Flexibility, Isokinetic Strength, Goniometer

Introduction

Muscle strains, acute micro-tears in the muscle, are common amongst the physically active population. Strains of the lower body musculature make up a large percentage of the total number of injuries sustained during activity. The knee, ankle and thigh are the most common injuries sites found among sports that predominantly use the lower extremity[1]. The thigh muscles i.e., the hamstrings and quadriceps, are strong and explosive muscles that span the entire upper leg and cross the knee joint. They work to provide opposing movements, flexion and extension, at the knee as well as the hip. With the large muscle mass and their antagonist relationship, the hamstrings and quadriceps are highly susceptible to injury[2]. The mechanism by which each of the muscle groups is injured is unique to the activity performed. However, eccentric movement, or contraction of the quadriceps and hamstrings appears to be the common mechanism of injury for most strains of the thigh muscles.

Adequate muscular strength, power, and joint flexibility are essential for injury prevention, in addition to safe and successful athletic performance[3]. Stretching is the most commonly used mechanism to increase flexibility. Increased muscle flexibility will allow muscle tissue to accommodate to imposed stress more easily and allow for efficient and effective movement[4]. Previous interventions have been used to prevent lower extremity injuries, such as stretching and range of motion exercises. Knight and colleagues performed a study comparing superficial heat, deep heat, and active exercises on the extensibility of the plantar flexor group in the lower leg[5]. The study evaluated four different treatment groups over four weeks of treatment. The treatment groups included: a stretching program without warm-up, a stretching program paired with active warm-up with no heat, a hot pack application at ~80° Celsius for 15 minutes and stretching, and continuous ultrasound at a setting of 1.0 MHz +/- 0.2% at 1.5 W/cm^2 for 7 minutes and stretching[5]. The study concluded that there was an increase in plantar flexion range of motion in all treatment groups. However, there was no significant difference in the increase of range of motion to determine which treatment combination is best in improving range of motion.

Static stretching has also been used to prevent lower extremity injuries. In a study conducted by Bandy and Irion[6], researchers examined the effect of time on static stretching in hamstring flexibility to determine the most effective therapeutic stretch time. The participants were divided into three groups of which the stretching protocol was identical; stretching was to be completed five times a week for six weeks by standing erect, standing on the left foot with the right foot placed on a plinth or chair with their toes directed towards the ceiling, and with the knee extended. The amount of time for which the stretch was held varied amongst the groups. The times investigated were 15 seconds, 30 seconds, and 60 seconds, respectively. The study concluded that hamstring range of motion significantly increased when stretching was done for 30 to 60 seconds but there was no difference between each other. The results revealed no difference in range of motion amongst the 15 second stretch group[6].

Dynamic stretching is another technique used to prevent injuries by increasing range of motion. A study conducted by Bandy et al.[4] compared the impact of static stretching and dynamic stretching on hamstring flexibility. The group performing the dynamic stretching was positioned supine holding their hip in 90 degrees of flexion. The group then actively extended their leg for 5 seconds, held the leg at the end of knee extension for 5 seconds, and then slowly lowered the leg for 5 seconds. The static stretching group completed a sit and reach stretch for 15 seconds. The study found that both groups increased hamstring range of motion, but the static stretching group showed more extensibility gain than the dynamic stretching group[4].

Correcting muscular imbalances and improving muscle weakness can aid in injury prevention. Brown and colleagues compared the effects of plyometric training and traditional weight training on lower body strength, jumping ability, and power in dancers[7]. Prior to testing, baseline lower body power and maximum strength and power were recorded and tested once per week for six weeks total. The weight training group performed leg press, calf raises, leg curls, and leg extension at 80% of their one repetition max and increased by 5% during the next training session; whereas the plyometric group performed 96 “touches” per session, with a touch defined as a jump or a foot contact with the ground. In addition to the touches, the plyometric group performed depth jumps, step-ups, box jumps, and “froggies”. The results of the study concluded that both methods of training were effective in improving power and strength, although the weight training protocol improved total thigh and hamstring strength. The plyometric group showed gains in overall thigh strength during leg press and standing vertical jump, while the weight training group revealed improved strength with leg press and leg curls[7].

Kinesio Tape, (KT), has been recently introduced to health care. KT is an adhesive and highly elastic tape that is designed and applied with the intention of facilitating the body’s natural healing process while providing support and stability to muscles and joints without restricting the body’s range of motion[8]. With proposed therapeutic, rehabilitative and preventative benefits, the tape is being used more frequently. However, due to the youth of the tape and the taping technique, there is limited research done to successfully conclude the sustainability and effectiveness of the tape on muscular strength and elasticity. However, it has been anecdotally proposed to improve muscular elasticity and strength.

Several studies have been conducted to evaluate the effects of KT on different musculature. Huang et al. tested KT on the triceps surae muscle group and its immediate effect on vertical jump height[9]. The study found that the medial gastrocnemius contraction force increased during the jumping task when the tape was applied from origin to insertion. The study used electromyography (EMG) to determine the muscle contraction forces. It was concluded that there was no significant increase in vertical jump height[9]. Another study performed by Vercelli et al.[10] tested the immediate effects of KT on the quadriceps muscle strength using three different taping techniques: enhancing (tape applied from muscular origin to insertion to increase muscle fiber recruitment), inhibiting (tape applied from muscular insertion to origin to decrease muscle fiber recruitment), and placebo. The study found that between the three taping techniques, there was no significant change in muscle strength[10]. Lastly, research executed by Lumbroso and colleagues[11] compared hamstring and gastrocnemius range of motion as well as peak force production upon application of KT from origin to insertion in both muscle groups. The findings suggest that 15 minutes post-KT application, the gastrocnemius and hamstring groups showed an increase in range of motion when performing the straight leg raise (SLR) test. The research also found that they gastrocnemius group showed a significant increase in peak force production 15 minutes post-application. The peak force production of this group also increased two days after the tape's application. The hamstring group also revealed an improvement in peak force production, but only two days following KT application, suggesting a sustained effect of KT on force production of the hamstring and gastrocnemius muscles[11].

Much of the previous research has looked at the immediate effects of KT on the musculature or soft tissue of interest. However, the elastic qualities of the tape are proposed to be effective for three to five days[8]. Amongst the limited research, there are few studies that evaluate the long term effects of the tape. However, these studies only consider the effects of the KT one to two days after the application. Therefore, the purpose of our study was to measure and evaluate the changes in range of motion, strength, and power output of the hamstrings and quadriceps with KT application in female collegiate club athletes. Another purpose of our study was to examine the sustainability of the KT effects on range of motion, power output, and strength by testing three days post-application (in addition to baseline and immediately post-application).

With the proposed effects of KT improving muscle elasticity and strength, it is hypothesized that there will be an increase in knee flexion and hip flexion ranges of motion, strength, and power output in both hamstrings and quadriceps muscle groups at 3-days post-application as well as at immediately post-application when compared to baseline measurements.

Methods

Participants

All participants were selected based upon their involvement in non-collegiate sponsored club sports and active academic enrollment at the University of Wisconsin-Eau Claire. Sports of interest included rugby, lacrosse, volleyball and ultimate frisbee. Each sport requires vertical jump, lower extremity strength, and flexibility of the hip and/or knee joint in order to successfully perform the activity skills.

Participants in this study were voluntarily recruited via email. This process produced fifteen interested individuals. However, upon implementation of the participation selection criteria, two individuals were excluded from this study due to previous injury and voluntary discontinuation of their participation. Additional selection criteria included: no current injury, no contusion over the mid-belly of the quadriceps or hamstrings muscle, no allergy to adhesive spray or KT, and no involvement in other treatment studies.

The participants were assigned to their designated treatment groups based on their email response. Assignments were established by alternating treatment groups, resulting in seven participants in quadriceps treatment group and six in the hamstring treatment group. Table 1 reveals the characteristics of the participants according to their randomly assigned treatment groups. Participants voluntarily provided basic demographic information including: age, height, weight, years in school, and the number of years participating in their club sport.

Before completing any testing, the participants were asked to sign an informed consent form following a PowerPoint presentation regarding testing procedures, participant expectations, and potential participant risks. The presentation also addressed the issue of participant information confidentiality. Participants were informed that they have the right to discontinue their involvement in the study at any given time. The participants obtained a hard copy of the informed consent form as well as a copy of the cover letter. The study received an Institutional Review Board (IRB) approval to perform the testing required for data collection.

Instrumentation

Strength

The HumacNorm isokinetic machine was used to obtain sensitive results regarding bilateral hamstring and quadriceps strength. The particular brand used was CSMi Brand with the 2008 software. In a study by Webber & Porter[12], the researchers found that using the HumacNorm isokinetic machine provided better data analysis for strength and power. The study also compared the reliabilities of ankle isometric, isotonic and isokinetic strength and power. The results concluded that isokinetic measures of strength and power were associated with the highest relative reliability, at > 0.7, compared to isometric and isotonic measurements[12]. Each tester was a qualified investigator in administering the strength test using the HumacNorm.

Range of Motion

The manual two-arm goniometer was used to assess bilateral range of motion of the hip or knee joint. The hip joint was evaluated amongst the hamstrings treatment group and the knee joint was assessed for the quadriceps treatment group. The McFarlane brand goniometer was used to measure all participants. All testers were qualified investigators in administering the goniometer measurement evaluation. The two-arm goniometer is the most commonly used portable device used to evaluate range of motion. In a study performed by Nussbaumer et al.[13], 30 participants had hip flexion, abduction, adduction, internal rotation and external rotation measured using a goniometer. The study concluded that the conventional manual goniometer can be used with confidence for assessment. This being said with the acknowledgment that overestimations of range of motion are a common clinician error[13]. In this study, range of motion measurements were obtained by the same tester to obtain a more valid conclusion and avoid poor inter-rater reliability.

Power Output

The Vertec Jump Training System machine was used to assess the vertical jump height/power output aspect of the three tested variables. All testers were qualified investigators for administering Vertec machine testing. A study conducted by Caruso et al.[14] compared vertical jump height reliability data of a force plate platform to those concurrently derived from the Vertec. Results showed heights calculated from platform take-offs were slightly less reliable to Vertec values. The study concluded take-off from the force plate platform produced jump heights less reliable as compared to those derived from the Vertec machine[14]. In the present study, the power output measurements were collected by the same tester to obtain a more valid conclusion and avoid inter-rater reliability errors.

Kinesio Tape

The tape was applied during the second session of testing following the application of adhesive spray. The participants were asked to wear appropriate length shorts, no oils or lotions on their skin, or have excessive hair over the treatment area. The tape was applied to the appropriate muscle group according to their randomized group assignment. The measurement of the tape was taken from the insertion point of the muscle to the origin. This length measurement, in centimeters, was then used to calculate the amount of tape that was directly applied to the participant. The formula used is as follows:

Initial Length Measurement (cm) x .65
=
True Kinesio Tape Application Length (cm)

The calculation formula considers the amount of additional tension that will be applied to the tape by the tester. The desired amount of added tension is 35% as this is proposed to have a greater influence on the muscle tissue[8]. Once the desired tape length is determined the application process began. To begin the tape application process, the participant was asked to march in place for ten seconds to provide a neutral standing hip position. The tester then sprayed the appropriate area with the adhesive spray. The corners of the tape were rounded to prevent catching on clothing and ensure longer tape application. The tape was cut 16 cm, or eight 2 cm squares, on one end to create two equal strands. The two strands formed a "Y" around the insertion points of the muscle group of interest. Once the tape was cut, the participant was placed into a stretch position. For the hamstrings, participants were instructed to bend forward at the hips so as to touch their toes. For the quadriceps group, the participant held a towel around the foot and then was asked to perform a quadriceps stretch. The tape was then applied from origin to insertion to aid in facilitation of the muscle's action. The uncut end of the tape, called the anchor, was applied to the muscle origin. The "Y" strips were applied around the insertion of the muscle near the joint line. The strips did not cross the joint line. The hamstring origin was at the ischial tuberosity with the insertion at the posterior knee and fibular head. The quadriceps origin is the AIIS and the insertion was the anterior knee. Similar to the hamstring application, the tape did not cross the joint line but came to the superior portion of the patellar tendon. Once the tape was applied the participant is instructed to rub the tape for 1 minute for heat activation. Figure 1 shows the KT application for the quadriceps treatment group, while Figure 2 shows application for the hamstrings treatment group.

Figure 1. Quadriceps Treatment Group KT Application.

Figure 2. Hamstrings Treatment Group KT Application.

Procedures

Variable testing was completed through three measurement sessions. Each measurement session is completed within 72 hours of the last. The three measurement sessions included: baseline, immediately post-application, and 3-days post-application. During each measurement session, the dependent variables were administered to assess the non-fatiguing variable first and ending with the most fatiguing test. Thus, the variables were evaluated in the following order: bilateral hip or knee range of motion, vertical jump, and bilateral isokinetic strength. Each session was conducted using the same series of procedures and protocols. Sessions began in the Athletic Training and Education Center at the university with a warm-up period that included 7 minutes on a stationary bike at a comfortable pace followed by dynamic stretching. The stretches were dynamic movements which included: high knees, up-and-overs, gluteal kicks, and Frankenstein walks. The stretches were demonstrated and supervised by the tester during each session to ensure proper technique and safety of the participant.

Upon completion of the warm-up period, participants were escorted back to the Athletic Training and Education Center. Active and passive range of motion was assessed to evaluate flexibility of the quadriceps or hamstrings. To assess quadriceps range of motion, the participant began lying prone with their knee in full extension. The participant was then instructed to bend their knee as far as possible. After this active movement, an over-pressure was applied by another tester to obtain passive range of motion. To determine hamstring flexibility, the participant began lying supine with their knee in full extension and was then asked to raise their toes to the ceiling as far as they could. Following this active motion, an over-pressure was applied to achieve passive range of motion of the hip joint. The measurements were obtained using a manual two-arm goniometer, with the stationary arm bisecting the torso, the movement arm bisecting the femur and the fulcrum at the greater trochanter. To ensure proper patient positioning, the tester monitored the participant's hip to verify that they were bilaterally level on the table. Three trials were completed on each leg, with measurements alternating every time, which provided a rest period. Between each of the measurements, the patient was instructed to clear their hips in order to place them into a more neutral or normal position.

Following hip or knee range of motion measurements, vertical jump testing was conducted in the indoor gymnasium. The participants were asked to raise their dominant arm in the air to determine the initial height of the Vertec. The initial height was obtained when the bottom vane touches the tip of the middle finger. The participant was then asked to perform a double legged vertical jump and try to reach with their dominant hand higher than the lowest vane. No additional step was provided, as this was a static vertical jump test. A one minute rest period was provided between trials to allow for appropriate recovery. Three trials were recorded in inches. The vertical jump trials were calculated by measuring the difference between the double-legged jump height and the initial one-arm reach height. The average of the trials was used for statistical analysis.

The final variable to be measured was strength of the quadriceps and hamstrings. Strength will be measured using the isokinetic machine, HumacNorm. There was a fifteen minute rest period before strength testing began. Testing was done at 60 degrees per second and at 180 degrees per second. The measurements were taken from the seated position. In order to assist in the accuracy of the data, the machine was calibrated between each participant. Calibration instructions were provided by the software. All instructions were completed in order to appropriately calibrate the machine as well as to allow testing to commence.

From the seated position, the chair was adjusted according to the participant's comfort and ability to successfully complete full range of motion at the knee. Before making the participants individual adjustments, there are generalized measurements that were used as starting points. These generalized measurements include: back aft beginning at 15 degrees, dynamometer height of 8, dynamometer rotation of 40 degrees, chair rotation of 40 degrees, chair angle at 40 degrees, and monorail at 38. Adjustments were then made accordingly from these initial settings. The adjustments were then recorded into the software. Dynamometer arm length and range of motion are the settings that do not have an initial setting as leg length and range of motion is not easily generalized amongst a population.

Once adjustments were made and the personalized settings were entered into the software the patient was fully strapped in according to their comfort. There were straps that cross the torso and provide stability of the upper body during the exercise. Another strap was found around the thigh being tested. This strap was not too tight as to restrict range of motion. The patient made the appropriate changes as necessary. However, once testing began, straps were not further adjusted as this may skew the results.

Once testing began the patient was instructed to give maximal effort during the exercise. There were practice trials before the testing began as designated according to the software. Testers acknowledged the participant when the testing began and the participant was asked to move into flexion. These instructions were given at each speed of testing. There was a five minute break between each testing series to reduce the onset of fatigue. Testing was completed bilaterally. Equipment and software adjustments were made when testing of the contralateral extremity began. Every measurement session followed an identical variable testing sequence to establish consistency and reduce the likelihood of error. Session two served the purpose of identifying the immediate effects of KT application as it was applied prior to the dynamic warm-up. The participant was then instructed not to remove the tape prior to the final testing session in order to obtain data on the sustainability of the tape. Participants completed the subjective Global Rating of Change Scale (GROC) following the completion of all testing.

Statistical analyses

Our study design is a pretest-posttest, randomized group design. A 2-way repeated measures ANOVA was used for data analysis. The independent variable was treatment option (i.e., KT application). The dependent variables included range of motion, strength, and power output. Level of statistical significance was set at $p \leq 0.05$ and SPSS version 19.0 was used for all analyses.

Results

Thirteen participants completed the study. Table 2 provides the means ± SD by treatment group for each tested dependent variable analyzed in this study.

Range of Motion

Hamstring Group

One-way repeated measures ANOVA indicated there was a significant time effect on active hip flexion of the right limb, $F(1.44, 7.21)=8.91$, $p=.015$. As a follow-up analysis, paired samples t test indicated the mean active hip flexion increased from baseline (M=80.33, SD=14.34) and 3-days post-application (M=96.97, SD=11.57), $t(5)=3.54$, $p=.017$. There was a significance difference between baseline and immediately post-application (M=87.61, SD=14.20), $t(5)=-3.97$, $p=.01$. There was no significant difference between immediately post-application and 3-days post-application, $t(5)=-2.02$, $p=.099$.

A one-way repeated measures ANOVA was used to analyze the left limb. Using an alpha of .05, the analysis indicated a significant time effect on active hip flexion of the left limb, *F*(2.00, 10.00)=15.50, *p*=.001. A paired sample *t* test was used as a follow-up analysis. The *t* test revealed that the mean active hip flexion increased from baseline (M=80.72, SD=15.49) and immediately post-application (M=87.11, SD=14.46), *t*(5)=-2.64, *p*=.046. A significant difference was found between baseline and 3-days post-application (M=93.50, SD=12.97), *t*(5)=6.96, *p*=.001. There was no significant difference between immediately post-application and 3-days post-application, *t*(5)=-2.49, *p*=.055.

Quadriceps Group

One-way repeated measures ANOVA revealed that there was a significant time effect on active knee flexion of the right limb, *F*(1.38, 8.27)=3.06, *p*=.111. A paired samples *t*-test was conducted as a follow up to evaluate the effect of the one-way repeated measures ANOVA. The *t*-test indicated the mean active knee flexion increased between immediately post-application (M=133.14, SD=4.33) and 3-days post-application, *t*(6)=-3.47, *p*=.013. This analysis indicated no significant difference from baseline (M=133.05, SD=5.30) and 3-days post-application (M=136.29, SD=3.52), *t*(6). The *t*-test also showed a decrease from baseline (M=133.05, SD=5.30) and immediately post-application (M=133.14, SD=4.33), *t*(6)=-0.066, *p*=.950.

A significant time effect on active left limb knee flexion was revealed by the one-way repeated measures ANOVA with an alpha of .05, *F*(1.30, 7.81)=4.24, *p*=.068. A paired samples *t* test was utilized as the follow-up analysis. The *t* test showed that the mean active knee flexion increased between immediately post-application (M=130.61, SD=3.54) and 3-days post-application (M=134.24, SD=5.78), *t*(6)=-3.11, *p*=.021. There was no significant difference between baseline (M=130.24, SD=4.67) and immediately post-application, *t*(6)=-.324, *p*=.757. Also, there was no significance shown between baseline and 3-days post-application, *t*(6)=1.95, *p*=.100.

Isokinetic Strength

Hamstrings Group (Knee flexors)

A one-way repeated measure ANOVA indicated that there was not a significant relationship between time and hamstring strength. When testing the left knee flexors at 60 degrees per second, *F*(2.00, 10.00)=.303, *p*=.745. At 180 degrees per second, *F*(1.08, 5.40)=.421, *p*=.414, the left knee flexors revealed no significance between time and strength. Like the left side flexors, the one-way repeated measure ANOVA showed no significance in hamstring strength and time of the right limb. At 60 degrees per second, the flexors of the right limb indicated no significance with time and hamstring strength, *F*(1.40, 7.01)=.663, *p*=.493. At 180 degrees per second, the right limb knee flexors showed no significance, *F*(2.00, 10.00)=.106, *p*=.901.

Quadriceps Group (Knee extensors)

A one-way repeated measure ANOVA illustrates that there is no significance between time and quadriceps strength at both testing protocols. Testing of the left limb knee extensors at 60 degrees per second, $F(1.67, 10.01)=.453$, $p=.614$, and at 180 degrees per second, $F(1.23, 7.40)=.40$, $p=.589$, showed no significance between strength and time. Similar effects were revealed with analysis of the right limb. With testing the right limb at 60 degrees per second, $F(1.37, 8.21)=1.605$, $p=.250$, and at 180 degrees per second, $F(1.14, 6.86)=.801$, $p=.418$, there was no significance noted. No follow-up analysis was conducted due to lack of significance reported between quadriceps and hamstring isokinetic strength and time.

Power Output Performance

A two-way repeated measures ANOVA indicated no group x time interaction, $F(2.00, 22.00)=0.11$, $p = .901$. However, it indicates a significant time effect, $F(2.00, 22.00)= 5.80$, $p=.010$. There was no group effect, $F(1, 11)=1.59$, $p=.234$. A paired samples *t*-test revealed a significant difference in vertical jump scores between baseline (M=14.94, SD=1.68) and 3-day post-application (M=16.13, SD=1.77), $t(12)=-4.21$, $p=.001$. There was also a significant difference between immediately post-application (M=15.34, SD=2.03) and 3-day post-application, $t(12)=.036$, $p=-2.37$. There was no significant difference between baseline and immediately post, $t(12)=-1.00$, $p=.335$.

Subjective Global Rating of Change Scale (GROC). The GROC scale was administered at the end of the final session of testing. The total participant mean was calculated as 2.31 with a standard deviation of 1.75. Table 3 reveals mean ± SD according to each treatment group subjective reporting.

Table 1. Participant characteristics.

Variable	Hamstring Group (*n* = 6)	Quadriceps Group (*n* = 7)
Age (years)	21.0 ± 0.9 [a]	19.3 ± 1.1
Height (inches)	65.1 ± 2.3	66.7 ± 2.9
Weight (pounds)	150.8 ± 32.3	135.4 ± 12.3
Years in School	16.3 ± 1.6	15.4 ± 1.3
Club Participation (years)	2.3 ± 1.9	2.0 ± 0.1

[a](Values are mean ± SD).

Table 2. Descriptive statistics of dependent variables by time and group.

Session	Treatment Group	Mean	Standard Deviation
Active Range of Motion (Left Side)			
Baseline	Hamstrings	80.72	15.49
	Quadriceps	130.24	4.67
	Total	107.4	27.77
Immediately Post-Application	Hamstring	87.11	14.46
	Quadriceps	130.61	3.54
	Total	110.53	24.55
Three Days Post-Application	Hamstrings	93.50	12.97
	Quadriceps	134.24	5.78
	Total	115.43	23.10
Active Range of Motion (Right Side)			
Baseline	Hamstrings	80.33	14.34
	Quadriceps	133.05	4.33
	Total	108.72	29.12
Immediately Post-Application	Hamstrings	87.61	14.20
	Quadriceps	133.14	4.33
	Total	112.13	25.53
Three Days Post-Application	Hamstrings	96.97	11.57
	Quadriceps	136.29	3.51
	Total	118.15	21.87
Power Output Performance			
Baseline	Hamstrings	14.25	1.77
	Quadriceps	15.53	1.49
	Total	14.94	1.68
Immediately Post-Application	Hamstrings	14.82	2.9
	Quadriceps	15.79	.83
	Total	15.34	2.03
Three Days Post-Application	Hamstrings	15.48	2.32
	Quadriceps	16.69	1.01
	Total	16.13	1.77
Isokinetic Strength at 60 Degrees per Second (Left Extensors)			
Baseline	Hamstrings	103.67	20.13
	Quadriceps	90.29	28.31
	Total	96.46	24.86
Immediately Post-Application	Hamstrings	98.83	24.58
	Quadriceps	94.29	17.29
	Total	96.38	20.17
Three Days Post-Application	Hamstrings	99.00	27.00
	Quadriceps	95.14	13.89
	Total	96.92	20.08
Isokinetic Strength at 60 Degrees per Second (Right Extensors)			
Baseline	Hamstrings	100.67	33.38
	Quadriceps	114.86	31.12
	Total	108.31	31.66
Immediately Post-Application	Hamstrings	98.50	26.26
	Quadriceps	98.14	21.75
	Total	98.31	22.89

Three Days Post-Application	Hamstrings	100.83	29.25
	Quadriceps	98.57	18.72
	Total	99.62	23.09
Isokinetic Strength at 60 Degrees per Second (Left Flexors)			
Baseline	Hamstrings	75.33	10.39
	Quadriceps	74.71	30.08
	Total	75.00	22.30
Immediately Post-Application	Hamstrings	72.50	17.94
	Quadriceps	62.71	13.25
	Total	67.23	15.74
Three Days Post-Application	Hamstrings	73.33	17.52
	Quadriceps	67.71	15.65
	Total	70.31	16.10
Isokinetic Strength at 60 Degrees per Second (Right Flexors)			
Baseline	Hamstrings	74.17	22.76
	Quadriceps	87.43	40.78
	Total	81.31	33.09
Immediately Post-Application	Hamstrings	71.50	19.00
	Quadriceps	68.29	9.55
	Total	69.77	14.10
Three Days Post-Application	Hamstrings	69.67	18.85
	Quadriceps	67.57	15.42
	Total	68.54	16.37
Isokinetic Strength at 180 Degrees per Second (Left Extensors)			
Baseline	Hamstrings	60.00	11.40
	Quadriceps	68.29	29.92
	Total	64.46	22.81
Immediately Post-Application	Hamstrings	32.17	14.98
	Quadriceps	32.14	12.95
	Total	32.15	13.32
Three Days Post-Application	Hamstrings	64.83	19.30
	Quadriceps	66.71	11.49
	Total	65.85	14.90
Isokinetic Strength at 180 Degrees per Second (Right Extensors)			
Baseline	Hamstrings	59.83	16.62
	Quadriceps	70.86	21.58
	Total	65.77	19.51
Immediately Post-Application	Hamstrings	63.00	17.79
	Quadriceps	63.71	13.46
	Total	63.38	14.92
Three Days Post-Application	Hamstrings	62.67	23.46
	Quadriceps	68.00	11.46
	Total	65.54	17.40
Isokinetic Strength at 180 Degrees per Second (Left Flexors)			
Baseline	Hamstrings	50.83	8.06
	Quadriceps	55.57	23.36
	Total	53.38	17.49
	Hamstrings	53.00	13.19

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Immediately Post-Application			
	Quadriceps	49.43	10.69
	Total	51.08	11.54
Three Days Post-Application	Hamstrings	54.69	15.81
	Quadriceps	51.14	12.14
	Total	52.77	13.46
Isokinetic Strength at 180 Degrees per Second (Right Flexors)			
Baseline	Hamstrings	51.33	12.58
	Quadriceps	56.86	18.28
	Total	54.31	15.53
Immediately Post-Application	Hamstrings	51.50	15.29
	Quadriceps	50.00	10.97
	Total	50.69	12.58
Three Days Post-Application	Hamstrings	50.50	15.476
	Quadriceps	52.29	10.64
	Total	51.46	12.54

Table 3. Descriptive statistics of dependent variables by time and group.

Treatment group	GROC Score
Hamstring (n = 6)	1.7 ± 1.2 [a]
Quadriceps (n = 7)	2.9 ± 2.0
Total (n = 13)	2.3 ± 1.8

[a](Values are mean ± SD).

Discussion

The results suggest that KT does not increase strength when applied to the quadriceps or hamstrings of female club athletes. This finding is different from the positive results found by Huang and colleagues, who found that when KT was applied to the triceps surae muscle group EMG activity increased as well as vertical ground reaction force[9]. Potential limitations of this study could be tester reliability when setting up the Humac Norm. Calibration was completed before every participant. However, individualized numbers could have been entered incorrectly into the machine. The KT might have not shown an effect because if there was an increase, it was very small and not notable. There may have been a possible limitation in participant effort output as well. The participant may not have given a true maximal effort during isokinetic strength and/or power output testing.

According to Drouin et al., the effects of KT have been suggested to increase proprioception by providing constant cutaneous afferent stimulation through the skin[15]. When testing power output by using the Vertec, after KT was applied there was a significant vertical increase (in inches) shown from baseline to 3-days post-application. There was also significant vertical increase from immediately post-application application to 3-days post-application. However, there was no difference between the hamstring and quadriceps groups. These results agree with the tape stimulating the skin providing an increase in muscle activity[15]. These results are also in agreement with previous work by Csapo et al in which KT was applied to the plantar flexor group. The study found an increase in power output due to an increase in jumping performance[16]. Limitations in the Vertec testing power output may have been from less than maximal participant effort. The study may have found differences between the quadriceps and hamstring groups if the Vertec could measure smaller increments. When measuring height increase, the Vertec is measured in 0.5 inches. If the Vertec was measured in centimeters, we may have seen a more accurate and greater increase. To have an effective jump, in most situations before the push off movement begins, vertical jumping is achieved by a rapid extension of the hip, knee, and ankle joints[9].

The results suggest that KT has an effect on hamstring AROM from baseline to immediately post application and baseline to three day post application. The data also suggests that KT has no flexibility effects on the quadriceps group. Limitations in measuring flexibility may have been patient effort or tester validity. Within this study, the same tester was utilized during range of motion measurements. Therefore, tester reliability should have not been a problem in this study. Using a manual goniometer may have caused possible limitations to this study; although in a study performed by Nussbaumer et al., measuring flexibility they concluded that the conventional manual goniometer can be used with confidence for longitudinal assessment in the clinic with the acknowledgment that overestimations of range of motion are a common clinician error[13]. To obtain a more valid conclusion, the range of motion values should be obtained by the same rater or clinician.

Conclusion

Our study has revealed that the sustainability of the tape significantly influences muscular elasticity for the hamstrings and quadriceps muscle groups. It has also shown a positive impact on power output. The research suggests that the utilization of KT for long term use can be beneficial for athletic events that require increased hip and knee flexibility. As a result, increased flexibility may lead to enhanced power output. All of which may lead to improved overall sport performance. However, the proposed benefit of increased muscular strength remains inconclusive. Further research is required to obtain the functional impact of KT application on strength increases.

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Address for Correspondence

Sykora JL, University of Wisconsin-Eau Claire, Eau Claire, Wisconsin, USA, 54701. PHONE: (715) 577-0714; EMAIL: sykorajl@uwec.edu.

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