J. Phys. Ther. Sci. 36: 745–749, 2024

The Journal of Physical Therapy Science

Original Article

Effect of protective taping on knee eversion angle and jump height during single-leg vertical jumps in patients with anterior cruciate ligament reconstruction

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Abstract. [Purpose] Taping is often performed to prevent injury and injury recurrence. However, it is unclear how taping affects landing and jumping kinematics in patients undergoing anterior cruciate ligament reconstruction. Therefore, this study aimed to determine the kinematic effects caused by taping during single-leg vertical jumps in patients with anterior cruciate ligament reconstruction. [Participants and Methods] Ten young patients who underwent anterior cruciate ligament reconstruction were included. The maximum knee joint flexion angle, peak value of the vertical component of the floor reaction force, maximum knee joint eversion angle, and jumping height during a single-leg vertical jump were measured using a three-dimensional motion analyzer and compared among the following three groups: without taping, with protective taping using elastic tape, and with protective taping using non-elastic tape. [Results] There were no significant differences in the peak value of the vertical component of the floor reaction force or the maximum knee joint flexion angle among the three groups. The maximum knee joint eversion angle and jumping height were significantly lower in the elastic tape and non-elastic tape groups than in the non-taping group. [Conclusion] Anterior cruciate ligament taping does not affect the magnitude of the impact on the body and can decrease knee joint eversion. However, jumping height was lower in the two taping groups than in the no-taping group. There were no significant differences in the items studied between the two taping groups.
Key words: Anterior cruciate ligament (ACL) injury, Single leg vertical jump, Taping

(This article was submitted Aug. 6, 2024, and was accepted Aug. 30, 2024)

INTRODUCTION

Anterior cruciate ligament (ACL) injuries occur in 91% of cases during sports[1)]; 72% of these injuries are noncontact injuries[2)], which are more likely to occur during rapid deceleration movements such as landing[3)]. Reconstruction with an autologous tendon graft is the first choice of treatment to improve knee joint stability and prevent secondary cartilage or meniscus damage[4–6)]. However, ACL injuries have a very high recurrence rate, with 15–35% of reconstructive patients reported reinjury to their ACLs[7, 8)]. The landing biomechanics of ACL reconstruction patients, when compared to those of normal individuals and normal limbs, result in a smaller knee flexion angle, a landing with a greater vertical floor reaction force component, and greater knee joint eversion[9–11)]. These findings are consistent with the risk factors for ACL injury[12–14)]; moreover, changing landing kinematics are emphasized as kinematic risk factors for reinjury.

After ACL reconstruction surgery, taping may be applied to enable early return to sports and prevent reinjury. Previous studies show that taping is effective in reducing antero-posterior tibial translation and knee joint eversion in cadaveric

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models[15], and that the angle of knee joint eversion is reduced during side stepping in healthy individuals[16]. However, the effect of taping on the kinematic risk factors for ACL injury in ACL-reconstructed patients is unclear. As mentioned earlier, ACL-injured patients have different landing biomechanics than healthy individuals and the healthy limb, so to determine the risk-reducing effect of taping on landing, it is necessary to validate it in ACL-injured patients. Furthermore, although previous studies have reported that taping to the ankle joint decreased jumping distance[17], since the knee joint contributes significantly to landing and jumping[18, 19], it is conceivable that restricting knee joint motion by taping would affect landing and jumping performance, but we have found no studies on this topic.

An index that can evaluate both landing and jumping is Single Leg Vertical Jump. This involves falling from a standing position on a platform and performing a vertical jump with maximum effort immediately after landing on one leg[18]. This assessment is often used as a return-to-sport criterion for patients with ACL injuries[19]. Single Leg Vertical Jump has evaluated the biomechanics of landing[20, 21] and jumping height[19, 22] for patients with ACL injuries, but kinematic changes due to taping have not been tested.

Common tapes used for taping include nonelastic tapes and elastic tapes (that can be stretched by approximately 30%). Nonelastic tape restricts joint movement, increases proprioceptive feedback, and enhances stability[23, 24]. Elastic tapes stabilize joints[25, 26] and are effective in reducing pain and improving physical function[27]. Different types of tape have different characteristics, but the kinematic effects of different types of tape on ACL reconstruction recipients are unclear.

We hypothesized that ACL protection taping would decrease the kinematic risk among ACL-reconstructed patients, but decrease the jumping height. We also postulate that this was more likely to occur with nonelastic tape than with elastic tape.

PARTICIPANTS AND METHODS

Ten ACL-reconstructed patients (7 women and 3 men, mean age 21.3 ± 2.6 years, mean height 168.4 ± 4.4 cm, mean weight 68.1 ± 10.8 kg) participated in the study. The selection criteria for the participants were patients who had undergone reconstructive surgery for a non-contact ACL injury during sports, were allowed by their physicians to return to sports, and could provide free and voluntary consent to participate in the study. The exclusion criteria were a previous diagnosis of a serious orthopedic or central nervous system disorder other than ACL injury or the presence of lower extremity pain. The two most common reconstructive procedures for ACL injuries, autologous hamstring tendon grafting and bony patellar tendon grafting, have been reported[28–30] with similar postoperative outcomes, but different rates of pain and knee flexion muscle strength[31]. Therefore, only patients who underwent reconstruction with autologous hamstring tendon grafts were included to control for these conditions. All participants were informed in writing and orally about the participant's protection and priority of rights, freedom to participate or discontinue, and the content of the study under the Declaration of Helsinki. Informed consent was obtained from each participant. The Research Ethics Review Committee of Sendai Seiyo Gakuin College approved this study (approval number: 0504).

A three-dimensional motion analyzer (Vicon Motion Systems, Oxford, UK) consisting of ten infrared cameras and two floor reaction force gauges (Kistler, Winterthur, Switzerland) was used to measure the participant's movements. The sampling frequency was set at 100 Hz for both the infrared camera and floor reaction force meter. The three-dimensional motion analyzer was synchronized with floor reaction force transducers. VICON NEXUS ver. 2.8.2 (Oxford, UK) was used as measurement software.

Kinematic data were obtained by affixing 14-mm-diameter infrared reflective markers to various parts of the participant's body and photographing the markers' coordinate 10 infrared cameras. The positions of the infrared reflective markers were as follows: top of the head, right and left temporal heads, spinous process of the 7th cervical vertebra, spinous process of the 8th thoracic vertebra, sternocervical cut scar, sternocleidomastoid process, right and left acromion, right and left humerus lateral epicondyle, right and left radial stapes, right and left superior anterior iliac spine, right and left superior posterior iliac spine, right and left hip joint, medial front surface of the right and left thigh, medial front surface of the right and left lower thigh, right and left exocarp, right and left endocarp, right and left heel, right and left 1st midfoot bone, right and left 5th midfoot bone. In addition, two sets of three nonidentical linear three-point markers were affixed to the outer portions of the thigh and lower leg, which were not covered by taping, resulting in a total of 39 markers. The hip joint was also affixed to a point 1/3 of the distance from the bottom of the greater trochanter reappearance on the line connecting the greater trochanter reappearance and the superior anterior iliac spine.

The Single Leg Vertical Jump was carried out from a 30 cm step. The participant was asked to drop from the step with the operated lower limb and on hitting the ground, immediately jump as high as possible while spending as little time as possible on the force plate. The participant was instructed to keep their hands on their hips during the task. The task was performed under three conditions: without protective taping, taping with elastic tape (Nitreat, Tokyo, Japan), and taping with non-elastic tape (Nitreat, Tokyo, Japan). The order in which these three conditions were performed was random. Several practice trials were conducted to enable the participants to perform the vertical jumps in the correct fashion. Subsequent trials were repeated until data from 5 successful trials were achieved. Trials that were able to remain in place for 3 seconds after landing were considered successful, and trials that lost balance were excluded.

Standard ACL protection taping procedures were performed by a licensed and experienced physical therapist who was a certified athletic trainer based on the Japan Sports Association Certified Athletic Trainer's Handbook[32]. The participants' skin was shaved and washed before taping, and taping was applied after ensuring that the skin was sufficiently dry. The participant placed the lower leg on the ACL reconstruction side forward, a 3-cm platform under the heel, a weight on the foreleg, and tensed the muscles around the knee joint with the knee in mild flexion. The taping was performed in the following order: anchor, anterior support, medial longitudinal support, medial X support, spiral tape, split tape, and anchor.

The maximum knee joint flexion angle, the maximum value of the vertical component of the floor reaction force, the maximum knee joint eversion angle, and the jumping height were measured for the single leg vertical jump under three conditions: without taping, taping with elastic tape, and taping with non-elastic tape. The maximum knee joint flexion angle, the maximum vertical component of floor reaction force, and the maximum knee joint eversion angle were extracted from the maximum values at the time of landing in the single leg vertical jump. The jumping height was calculated by subtracting the height of the center of gravity in the stationary standing position from the maximum height of the center of gravity during jumping. For later statistical analysis, these outcomes were averaged over five successful trials. The significance level for all statistical analyses was set at $p<0.05$. SPSS Statistics 22 (SPSS Japan Inc., Tokyo, Japan) was used as the statistical software. Each outcome was confirmed to follow a normal distribution using the Shapiro–Wilk test, and repeated measures analysis of variance and Tukey's post-hoc test was performed.

RESULTS

The maximum knee joint flexion angle and maximum vertical component of the floor reaction force were not significantly different among the three groups. The knee joint eversion angle was significantly lower in the elastic tape and nonelastic tape groups than in the non-taping group (Table 1). There were no differences in outcomes between the two taping techniques.

DISCUSSION

The purpose of this study was to evaluate the effect of protective taping on ACL-reconstructed patients. The results showed that ACL protective taping did not change the knee flexion angle or the vertical component of floor reaction force during single leg vertical jump, but it significantly reduced the knee eversion angle. This indicates that ACL protection taping can suppress the knee joint eversion angle at landing, which is a risk factor for ACL injury, without increasing the impact on the body. These results support the hypothesis and are consistent with previous studies in healthy individuals[16)]. This study demonstrates that taping is effective in reducing the risk of landing in patients with ACL injuries.

To determine the effect of taping on athletic performance, we also measured jump height[19)], which is appropriate for assessing knee function among ACL-reconstructed patients. The results revealed that jumping height was decreased by taping, which may have caused a decrease in athletic performance. Patients with ACL injuries may need to sacrifice some performance in exchange for reduced risk on landing by applying ACL protective taping.

There were no statistically significant differences in the joint angle, vertical component of the floor reaction force, or jumping height between the two types of tape (elastic and nonelastic), and we did not detect any difference in effectiveness between the two types of tape. This result contradicted our hypotheses. We believe that the tape-wrapping method and the degree of stretch used to wrap the elastic tape contributed to this result. There are various methods of wrapping the tape, and it is conceivable that the effect on joint braking power and athletic performance may differ depending on the wrapping method and the degree of tension used when applying the tape.

This study has several limitations. First, we cannot measure strain differences directly against the ACL, which is responsible for 63–77% of the tibial anterior shear force braking[33)], but we do not know how well taping reduces tibial anterior shear forces in vivo. In cadaveric models, previous studies have shown that taping can reduce tibial anterior shear forces[15)]. A factor significantly involved in increasing tibial anterior shear force is the tension of the quadriceps muscle attached to the proximal anterior surface of the tibia, and it has been reported that activity at shallow knee flexion angles significantly increases ACL strain[12)], but no decrease in knee flexion angle was observed with taping in the present study. In addition, although this study used jump height as a measure of exercise performance for ACL-reconstructed patients, other measures should be considered

Table 1. Difference in Single Leg Vertical Jump with and without taping and type of taping

	Without taping	Elastic tape	Nonelastic tape	Tukey HSD
Maximum knee joint flexion angle (°)	63.87 ± 4.80	62.84 ± 8.96	62.94 ± 6.38	
Maximum floor reaction force vertical component (N/BW)	22.74 ± 4.99	22.08 ± 4.80	22.23 ± 4.15	
Maximum knee joint eversion angle* (°)	7.05 ± 1.97	5.38 ± 1.85	4.04 ± 2.58	W >E, N
Jumping height* (m)	0.25 ± 0.03	0.23 ± 0.03	0.21 ± 0.04	W >E, N

Values are mean ± SD, n=10. *p<0.05.
HSD: honestly significant difference; W: without taping; E: elastic tape; N: nonelastic tape; SD: standard deviation.

and discussed. The effects of ACL protective taping on functional movement have not yet been fully investigated, and there is room for further research.

In conclusion, in terms of preventing ACL reinjury, ACL protective taping can reduce knee joint eversion. On the other hand, jumping height is reduced, which may decrease athletic performance. No kinematic differences were found between the types of tape used for taping.

Funding

This study was supported by Grants-in-Aid for Research from the Sendai Seiyo Gakuin College (Gakucho0509) to Yoshinori Komatsu.

Conflict of interest

The authors declared no conflict of interest.

REFERENCES

1) Paul JJ, Spindler KP, Andrish JT, et al.: Jumping versus nonjumping anterior cruciate ligament injuries: a comparison of pathology. Clin J Sport Med, 2003, 13: 1–5. [Medline] [CrossRef]
2) Boden BP, Dean GS, Feagin JA Jr, et al.: Mechanisms of anterior cruciate ligament injury. Orthopedics, 2000, 23: 573–578. [Medline] [CrossRef]
3) Hurd WJ, Axe MJ, Snyder-Mackler L: A 10-year prospective trial of a patient management algorithm and screening examination for highly active individuals with anterior cruciate ligament injury: part 1, outcomes. Am J Sports Med, 2008, 36: 40–47. [Medline] [CrossRef]
4) Tsoukas D, Fotopoulos V, Basdekis G, et al.: No difference in osteoarthritis after surgical and non-surgical treatment of ACL-injured knees after 10 years. Knee Surg Sports Traumatol Arthrosc, 2016, 24: 2953–2959. [Medline] [CrossRef]
5) Brambilla L, Pulici L, Carimati G, et al.: Prevalence of associated lesions in anterior cruciate ligament reconstruction: correlation with surgical timing and with patient age, sex, and body mass index. Am J Sports Med, 2015, 43: 2966–2973. [Medline] [CrossRef]
6) Krause M, Freudenthaler F, Frosch KH, et al.: Operative versus conservative treatment of anterior cruciate ligament rupture. Dtsch Arztebl Int, 2018, 115: 855–862. [Medline]
7) Webster KE, Feller JA: Exploring the high reinjury rate in younger patients undergoing anterior cruciate ligament. Am J Sports Med, 2016, 44: 2827–2832. [Medline] [CrossRef]
8) Wiggins AJ, Grandhi RK, Schneider DK, et al.: Risk of secondary injury in younger athletes after anterior cruciate ligament reconstruction: a systematic review and meta-analysis. Am J Sports Med, 2016, 44: 1861–1876. [Medline] [CrossRef]
9) Larwa J, Stoy C, Chafetz RS, et al.: Stiff landings, core stability, and dynamic knee valgus: a systematic review on documented anterior cruciate ligament ruptures in male and female athletes. Int J Environ Res Public Health, 2021, 18: 3826. [Medline] [CrossRef]
10) Delahunt E, Sweeney L, Chawke M, et al.: Lower limb kinematic alterations during drop vertical jumps in female athletes who have undergone anterior cruciate ligament reconstruction. J Orthop Res, 2012, 30: 72–78. [Medline] [CrossRef]
11) Hewett TE, Myer GD, Ford KR, et al.: Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. Am J Sports Med, 2005, 33: 492–501. [Medline] [CrossRef]
12) DeMorat G, Weinhold P, Blackburn T, et al.: Aggressive quadriceps loading can induce noncontact anterior cruciate ligament injury. Am J Sports Med, 2004, 32: 477–483. [Medline] [CrossRef]
13) Cerulli G, Benoit DL, Lamontagne M, et al.: In vivo anterior cruciate ligament strain behaviour during a rapid deceleration movement: case report. Knee Surg Sports Traumatol Arthrosc, 2003, 11: 307–311. [Medline] [CrossRef]
14) Withrow TJ, Huston LJ, Wojtys EM, et al.: The effect of an impulsive knee valgus moment on in vitro relative ACL strain during a simulated jump landing. Clin Biomech (Bristol, Avon), 2006, 21: 977–983. [Medline] [CrossRef]
15) Anderson K, Wojtys EM, Loubert PV, et al.: A biomechanical evaluation of taping and bracing in reducing knee joint translation and rotation. Am J Sports Med, 1992, 20: 416–421. [Medline] [CrossRef]
16) Huang YL, Lin KW, Chou LW, et al.: Immediate effect of anterior cruciate ligament protective knee taping on knee landing mechanics and muscle activations during side hops. Int J Environ Res Public Health, 2021, 18: 10110. [Medline] [CrossRef]
17) Boda H, Hirose N: The effect of taping and fatigue on ankle joint for bounding performance. Jpn J Athl Train, 2018, 3: 149–157.
18) Kotsifaki A, Korakakis V, Graham-Smith P, et al.: Vertical and horizontal hop performance: contributions of the hip, knee, and ankle. Sports Health, 2021, 13: 128–135. [Medline] [CrossRef]
19) Kotsifaki A, Van Rossom S, Whiteley R, et al.: Single leg vertical jump performance identifies knee function deficits at return to sport after ACL reconstruction in male athletes. Br J Sports Med, 2022, 56: 490–498. [Medline] [CrossRef]
20) Uhlár Á, Ambrus M, Lacza Z: Dynamic valgus knee revealed with single leg jump tests in soccer players. J Sports Med Phys Fitness, 2023, 63: 461–470. [Medline] [CrossRef]
21) Chijimatsu M, Ishida T, Yamanaka M, et al.: Landing instructions focused on pelvic and trunk lateral tilt decrease the knee abduction moment during a single-leg drop vertical jump. Phys Ther Sport, 2020, 46: 226–233. [Medline] [CrossRef]
22) Giacomazzo Q, Picot B, Chamu T, et al.: Impaired symmetry in single-leg vertical jump and drop jump performance 7 months after ACL reconstruction. Orthop J Sports Med, 2024, 12: 23259671241263794. [Medline] [CrossRef]
23) Perrin D: Athletic taping and bracing, 2nd ed. Champaign: Human Kinetics, 2005.
24) Kuni B, Mussler J, Kalkum E, et al.: Effect of kinesiotaping, non-elastic taping and bracing on segmental foot kinematics during drop landing in healthy subjects and subjects with chronic ankle instability. Physiotherapy, 2016, 102: 287–293. [Medline] [CrossRef]

25) Delahunt E, O'Driscoll J, Moran K: Effects of taping and exercise on ankle joint movement in subjects with chronic ankle instability: a preliminary investigation. Arch Phys Med Rehabil, 2009, 90: 1418–1422. [Medline] [CrossRef]
26) Crossley KM, Marino GP, Macilquham MD, et al.: Can patellar tape reduce the patellar malalignment and pain associated with patellofemoral osteoarthritis? Arthritis Rheum, 2009, 61: 1719–1725. [Medline] [CrossRef]
27) Ye W, Jia C, Jiang J, et al.: Effectiveness of elastic taping in patients with knee osteoarthritis: a systematic review and meta-analysis. Am J Phys Med Rehabil, 2020, 99: 495–503. [Medline] [CrossRef]
28) Xie X, Liu X, Chen Z, et al.: A meta-analysis of bone-patellar tendon-bone autograft versus four-strand hamstring tendon autograft for anterior cruciate ligament reconstruction. Knee, 2015, 22: 100–110. [Medline] [CrossRef]
29) Webster KE, Feller JA, Hartnett N, et al.: Comparison of patellar tendon and hamstring tendon anterior cruciate ligament reconstruction: a 15-year follow-up of a randomized controlled trial. Am J Sports Med, 2016, 44: 83–90. [Medline] [CrossRef]
30) Zoran Z, Ivan V, Egon B, et al.: Knee stability after arthroscopic anterior cruciate ligament reconstruction using the middle third of the patellar ligament and quadrupled hamstring tendons grafts—a two-year follow-up. Injury, 2015, 46: S91–S95. [Medline] [CrossRef]
31) Ciccotti MC, Secrist E, Tjoumakaris F, et al.: Anatomic anterior cruciate ligament reconstruction via independent tunnel drilling: a systematic review of randomized controlled trials comparing patellar tendon and hamstring autografts. Arthroscopy, 2017, 33: 1062–1071.e5. [Medline] [CrossRef]
32) Syuumei I, Tokuyoshi K, Ziro K: Certified athletic trainer specialty textbook (6) prevention and conditioning. Tokyo: Japan Amateur Athletic Association, 2007, p 240.
33) Ball S, Stephen JM, El-Daou H, et al.: The medial ligaments and the ACL restrain anteromedial laxity of the knee. Knee Surg Sports Traumatol Arthrosc, 2020, 28: 3700–3708. [Medline] [CrossRef]