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Eccentric Exercise, Kinesiology Tape, and Balance in Healthy Men

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Context: Deficits in balance have been identified as a possible risk factor for knee injuries in athletes. Despite a lack of evidence for its effectiveness, kinesiology tape (KT) is widely used to prevent knee injuries.

Objective: To investigate the influence of KT at the knee joint on balance ability in healthy men after eccentric exercise.

Design: Crossover study.

Setting: University laboratory.

Patients or Other Participants: Twelve young men with no history of lower limb injury volunteered for the study (age = 23.3 ± 2.6 years). All participants were students enrolled in a sports science program.

Intervention(s): Participants performed the balance test with and without KT at the knee joint on 2 separate days.

Main Outcome Measure(s): The ability to maintain balance was assessed during a single-legged–stance test using a computerized balance-stability test system. The test was performed before and after 30 minutes of downhill walking on a treadmill.

Results: Eccentric exercise resulted in a deterioration of balance ability, which was attenuated by the use of KT. Further analyses revealed that the effectiveness of KT depended on the participant's balance status, with the preventive effect being greater in participants presenting with poorer baseline balance ability.

Conclusions: Applied to the knee joint, KT counteracted the exercise-related deterioration of balance ability observed when no tape was used. Participants presenting with below-average balance ability received more benefit from KT. By preventing exercise-related impairment of balance ability, KT might help to reduce the risk of sport-associated knee injuries.

Key Words: Kinesio tape, knee joint, proprioception, muscle fatigue, injury prevention

Key Points

- Eccentric exercise led to a deterioration of balance ability in healthy young men.
- Kinesiology tape applied to the knee joint attenuated the degree of exercise-related fatigue and associated impairment of balance ability.
- The protective effect of kinesiology tape was more pronounced in participants presenting with poor baseline balance ability.

The maintenance of *balance*, which is the process of keeping the body's center of gravity over the body's base of support,[1] is an essential requirement for both sports and activities of daily living. The control of balance relies on continuous feedback from visual, vestibular, and somatosensory and proprioceptive structures.[2] Balance ability is negatively affected by muscle fatigue induced by whole-body exercises such as walking, running, or cycling.[3–5] Such types of physical activity involving large muscle groups may deteriorate an individual's capacity to process sensory proprioceptive and exteroceptive information and decrease the efficiency of the muscular system.[4,5] As Changela et al[6] revealed, knee proprioception was impaired in healthy individuals after a moderate-fatigue exercise protocol, leading to deficits in balance ability. In particular, fatigue of muscles acting on the knee joint seemed to negatively affect balance.[7,8]

Clinically, a negative consequence of balance deterioration resulting from physical fatigue is an increased risk of knee injuries,[6,7] which account for almost 40% of all injuries in athletes, and thus represent one of the most common forms of injury.[9,10] Because knee injuries are known to be associated with negative, long-term implications (eg, chronic joint instability, altered muscle reflexes, limitation of performance), the treatment of which necessitates significant health care expenditures, developing preventive measures is of utmost importance.[10,11] Particularly in recent years, the use of Kinesio tape, often also referred to as kinesiology tape (*KT*), has become extremely popular within the sporting community to reduce the severity and incidence of knee injuries. Kinesio tape, invented by the chiropractor Kenzo Kase in the 1970s, is a thin, air-permeable, water-resistant, and elastic adhesive tape that can be stretched to up to 120% to 140% of its resting length.[12] After application, its tendency to recoil to its original length provides a constant pulling force on the skin.

One of the purported benefits of KT is improved proprioception through increased stimulation of mechanoreceptors in skin, muscles, and joint capsules.[12] Studies directly investigating this claim have shown that force sense may indeed be improved by the application of KT.[13,14] Although resting joint position sense appears largely unaffected by taping interventions,[15] investigations by our team[16] and others[17] also suggest that KT could help attenuate fatigue-associated impairment in this proprioceptive measure. As proprioceptive acuity plays an essential role in maintaining balance,[2,6,18] it is plausible to assume that enhancements in knee proprioception from KT would be reflected by enhanced balance. Positively influencing balance would not only benefit performance but also be advantageous for injury prevention in healthy athletes. Although the results have been somewhat equivocal,[19,20] most authors[21–23] reported no influence of KT on balance as measured in the resting state in healthy participants. To the best of our knowledge, only 2 groups[24,25] have examined the effects of KT on balance ability under the concomitant influence of muscle fatigue, as provoked by isometric knee extension or Bulgarian squats.

The purpose of our study was to investigate the effect of KT on balance ability after eccentric exercise in a group of healthy young men. We hypothesized that KT applied to the anterior thigh and knee would mitigate or even prevent the exercise-related deterioration in balance ability expected when no tape was used. Furthermore, we proposed that men with poor balance ability would benefit more from the application of KT.

METHODS

Participants

Twelve healthy male sports science students (age = 23.3 ± 2.6 years, height = 181.6 ± 4.5 cm, weight = 77.8 ± 7.0 kg) at the University of Innsbruck volunteered for this study. Participants reported being recreationally active in various sport disciplines, including basketball, climbing, cycling, gymnastics, swimming, and volleyball at least 5 days per week. However, they did not engage in any competitive sports. None had a history of major or minor hip, knee, or ankle injury or other condition or neurologic disease. We determined the sample size via an a priori power analysis based on normative data published by the manufacturer of the Biodex Balance System (http://www.biodex.com; Biodex Medical Systems, Shirley, NY). We considered the performance differences between the youngest (18–35 years) and second youngest (36–53 years) groups, for whom normative values had been reported, the minimum threshold for functionally relevant improvements in balance performance. To recognize an effect size of this dimension as statistically significant ($dz = 0.77$; $\alpha = .05$; $1 - \beta = 0.8$), a minimum of 12 participants had to be included.

All participants completed the scheduled test protocol. Participants gave written informed consent, and the study was approved by the Institutional Review Board and the Ethics Committee of the University of Innsbruck.

Procedures

To provide reproducible environmental conditions, we carried out the measurements in a climatic chamber (custom model; Kältepol, Natters, Austria) at the Department of Sport Science of the University of Innsbruck. The room temperature was set to 23°C at a relative humidity of 50%. Participants, who were requested to wear shorts and sports shoes, performed the test twice in a randomized order: once without the use of KT (untaped) and once with KT applied to the knee joint of the dominant leg. Testing days were separated by 1 week. The *dominant leg* was defined as the leg preferentially used to jump (right side in 7 participants). Kinesiology tape was applied at the beginning of the day of testing and worn by participants for the duration of the measurements.

The eccentric exercise protocol consisted of 30 minutes of downhill walking at a 20% decline on a treadmill (model Pulsar; h/p/cosmos sports & medical Gmbh, Traunstein, Germany). A natural walking speed, contingent upon the participant's leg length, was calculated using the equation $v = \sqrt{2g} \cdot \pi^{-1} \cdot \sqrt{l} + l$, where l represents the length of the leg (m) and g is the gravitational constant (9.81 m/s^2).[26] As a warm up, participants walked uphill at an inclination of 20% for 5 minutes at a speed of 3 km/h.

Before and immediately after downhill walking, single-limb postural stability was evaluated using the Biodex Balance System. This system consists of a circular unstable platform that permits up to 20° of tilt in any plane and has a measuring accuracy of 0.1°. The system allows testing at varying levels of difficulty, ranging from level 8, which is the most stable, to level 1, representing the greatest instability. An integrated computer records the degree of platform displacement from the initial level and calculates an overall stability index (OSI) according to the equation

$$\mathrm{OSI} = \sqrt{\sum(0 - X)^2 + \sum(0 - Y)^2 \cdot n^{-1}},$$

where X and Y represent the deviations in the right-to-left and anterior-to-posterior directions, respectively, and n is the number of measurements. Higher stability indices indicate poorer postural stability. In addition, the system calculates the relative amount of time spent in balance zones representing different degrees of platform tilt from the neutral position (zone A = 0°–5°, zone B = 6°–10°, zone C = 11°–15°, zone D = 16°–20°). Greater percentages of time spent in balance zone A ($t_{\text{zone-A}}$) imply that the platform has been kept level for longer periods, which reflects better balance ability. Two previous groups[27,28] have tested the reliability of the Biodex Balance System as an appropriate tool for posturography. Pincivero et al[27] found intraclass correlation coefficient values for OSI ranging from 0.6 for stability level 2 to 0.95 for stability level 8 in healthy participants during 20-second trials with the dominant limb. Schmitz and Arnold[28] reported intraclass correlation coefficient values for dominant single-limb stance ranging from 0.82 and 0.80 for OSI, using decreasing stability levels from 8 to 2 over 30 seconds.

In our study, the platform was set to stability level 4 for all trials. Participants were asked to stand on the dominant leg in the central area of the balance platform, with their hands resting on their hips. This foot position remained unchanged during the measurement process. The nondominant leg was held with the knee flexed at a 90° angle, in a position of neutral hip extension with partial abduction, so as not to touch the test leg. Participants were instructed to keep the unstable platform as level as possible for 20 seconds while their eyes were open. During the tests, the Biodex computer screen was covered to eliminate visual feedback. All participants performed 1 practice trial and three 20-second test trials, which were interspersed by rest

Figure 1. The application of kinesiology tape at the quadriceps and knee joint on the dominant leg. 1 = tape for vastus lateralis muscle, 2 = tape for vastus medialis muscle, 3 = tape for patella.

periods of 30 seconds. For each test, a report of OSI and $t_{zone\text{-}A}$ was generated. The values of OSI (°) and $t_{zone\text{-}A}$ (%) obtained in 3 trials were averaged and used as dependent variables for further analysis.

Taping Technique

The participants were taped with 3 strips of KT (model Nasara Original Kinesiology Tape; MIKROS GmbH, Hamburg, Germany), which were applied over the quadriceps femoris muscle and knee of the dominant leg (Figure 1). According to Kase et al,[12] this taping technique provides mechanical stability to the knee joint and, thus, helps to protect it against excessive strain. During the application, participants sat with the knee flexed to 90°. The first strip of tape was applied to the skin over the vastus lateralis muscle and extended from 10 cm distal to the greater trochanter to the lateral edge of the patella. Subsequently, the tape was applied around the patella in a circular manner. For the vastus medialis muscle, another strip of KT was applied over its central third, from the medial region of the thigh to the medial edge of the patella. As with the strip applied to the vastus lateralis muscle, the tape's distal end was positioned circularly around the patella. It should be noted that the upper 3 cm of both tape strips were applied without stretching tension and, therefore, acted as anchor points. The portions between the anchor and the superior patella were stretched to approximately 75% of the maximal length. The portions applied around the patella were stretched to maximal tension. The ends remained unstretched and intersected. Finally, a third strip of tape with a length of 10 cm was placed over the patella at maximal tension.

Statistical Analysis

We analyzed all data for the 2 balance variables OSI and $t_{zone\text{-}A}$ using commercially available software (SPSS version 21.0; IBM Corp, Armonk, NY). Normality of data was assessed using Shapiro-Wilk tests. Two-way repeated-measures analyses of variance were used to investigate the influence of the main factors (time [before versus after downhill walking] and taping condition [untaped versus KT]), as well as their interactive effect on OSI and $t_{zone\text{-}A}$. Pearson correlation coefficients were calculated from analysis-of-variance results through F conversion and interpreted as measures of effect size. Furthermore, the Pearson coefficient was used for correlational analysis to test the relationship between the initial OSI value without KT and the exercise-related change with or without the use of KT (OSI after downhill walking with or without KT minus OSI before downhill walking untaped). The level of significance was set at $P \leq .05$, and values are reported as mean ± standard deviation.

RESULTS

The values of OSI and $t_{zone\text{-}A}$ at the measuring times before and after downhill walking by taping condition (untaped, KT) are summarized in the Table.

Overall, time had a main effect on OSI ($r = 0.722$, $P = .005$), with increased values of OSI after downhill walking. Although the OSI values were generally lower with the use of KT, the effect of taping condition failed to reach statistical significance ($P = .198$). However, the time × taping condition interaction effect was significant ($r = 0.555$, $P = .049$), indicating that the exercise-related change in OSI differed between the taping conditions. It is evident from Figure 2A that the exercise-related increase in OSI was 13.8% greater when KT was not used. The same result was observed for $t_{zone\text{-}A}$ (Figure 2B), with the time × taping condition interaction effect just reaching significance ($r = 0.555$, $P = .050$).

As shown in Figure 3, the application of KT limited the exercise-related deterioration of balance ability only in those participants whose baseline OSI values (as measured without KT before downhill walking) were high (ie, participants with initially poorer balance ability). Confirming this observation, the Pearson coefficient showed a significant negative correlation ($r = -0.652$, $P = .022$) between the baseline OSI value (without KT, before downhill walking) and the degree of exercise-related change in OSI with the use of KT. Higher baseline values coincided with smaller exercise-related changes when KT was used. It is important that no such negative correlation was found between baseline OSI and the exercise-related change in OSI when KT was not used ($r = 0.186$, $P = .563$).

DISCUSSION

The typical decline in balance that is a consequence of physical fatigue represents a potential risk factor for knee injuries in athletes.[6,7] The use of KT to prevent knee injuries has become increasingly popular among both competitive and recreational athletes. To scientifically

Table. Overall Stability Index (°) and Time Spent in Balance Zone A ($t_{zone\text{-}A}$) by Time and Taping Condition

Condition	Kinesiology Tape?	Time	Mean ± SD	95% Confidence Interval	Minimum	Maximum
Overall Stability Index, °						
Difference	No	Pre-exercise	2.5 ± 0.6	2.1, 2.9	1.5	3.7
		Postexercise	3 ± 0.9	2.4, 3.5	2	4.5
			0.5 ± 0.5	0.2, 0.8	−0.4	1.4
Difference	Yes	Pre-exercise	2.5 ± 0.7	2.1, 3.0	1.9	4.2
		Postexercise	2.6 ± 0.5	2.3, 3.0	2.1	3.7
			0.1 ± 0.4	−0.2, 0.3	−0.6	0.5
$t_{zone\text{-}A}$, %						
Difference	No	Pre-exercise	97.9 ± 4.4	94.4, 100.8	85.5	100
		Postexercise	94.8 ± 7.4	89.8, 99.7	78.5	100
			3.1 ± 4.3	0.3, 5.8	0	11.8
Difference	Yes	Pre-exercise	97.8 ± 3.9	95.2, 100.4	87.3	100
		Postexercise	98.2 ± 3.4	95.9, 100.4	88	100
			0.3 ± 2.6	−1.9, 1.3	−7.6	3.5

evaluate the efficacy of preventive taping applications during physical activity, we aimed to investigate the effect of KT on the performance of a computerized balance test by uninjured men before and after 30 minutes of downhill walking. Use of KT mitigated the exercise-related deterioration of balance ability observed when no tape was used.

Muscle fatigue is known to result in a deterioration of neuromuscular control in the lower extremities.[7] In addition, whole-body exercise, such as walking, running, or cycling, negatively affects balance ability by altering proprioceptive inputs.[3,4,5] Accordingly, several authors demonstrated deficits in knee proprioception after fatiguing exercise,[29,30] primarily through lost efficiency of the muscle receptors and secondarily through increased sensitivity of the capsular receptors.[31] Eccentric muscle actions, which are characteristic of downhill walking, produce muscle damage that deteriorates proprioception and consequently postural balance.[32–34] In agreement with previous authors,[6,8] our results showed a strong (r = 0.722) and significant decrease (P = .005) in balance ability as measured after 30 minutes of downhill walking. Indeed, comparison with data obtained in clinical cohorts indicated that the balance deterioration provoked by downhill walking (OSI before downhill walking = 2.5°, OSI after downhill walking = 2.9°) was only slightly smaller than that caused by rupture of the anterior cruciate ligament (OSI = 0.5°–0.7°).[35,36] The impaired balance may be related to desensitization of muscle spindles or Golgi tendon organs provoked by physical fatigue.[6,31]

Our finding that balance results were virtually unchanged after the eccentric exercise intervention when KT was applied to the knee suggests that use of this tape may counter the negative effect of physical exertion, thereby limiting or even preventing exercise-related impairment of balance ability. Although our data do not allow conclusions to be drawn about the underlying physiological mecha-

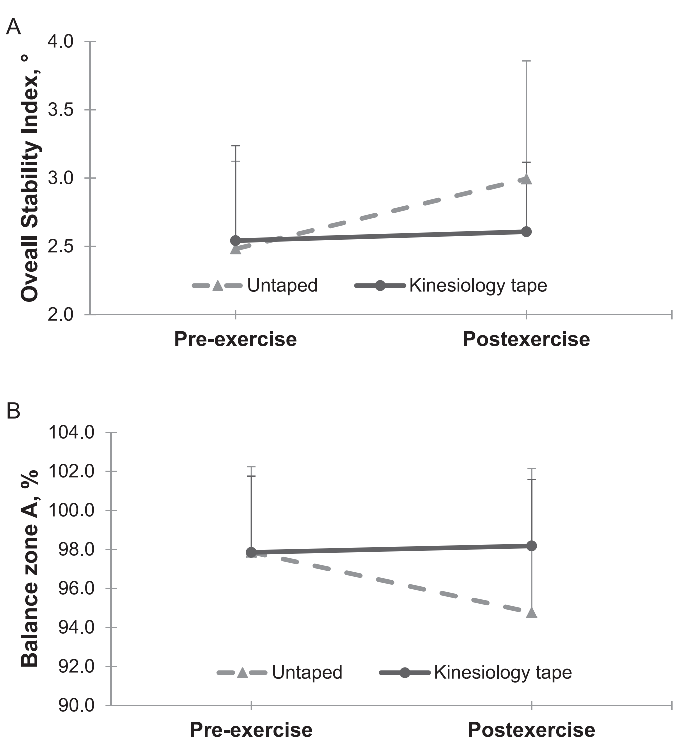

Figure 2. A, Overall stability index (OSI) and B, the relative amount of time spent in balance zone A as measured before and after downhill walking (pre-exercise and postexercise) between taping conditions (untaped and kinesiology tape). The exercise-related changes in values (calculated as the difference between postexercise and pre-exercise values) differed between the taping conditions (OSI: P = .049; time spent in balance zone A: P = .05). Note that the higher values of the OSI and lower values of the time spent in balance zone A reflect poorer postural control.

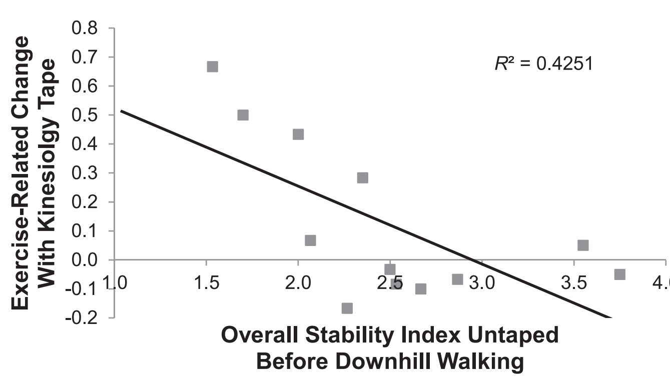

Figure 3. The exercise-related change in the overall stability index with the use of kinesiology tape (KT; calculated as the difference between the value after downhill walking with KT and the value before downhill walking without KT) by the baseline overall stability index (as measured without KT and before downhill walking).

nisms, researchers[14] have suggested that KT increases the sensory feedback from mechanoreceptors located in the skin, muscles, and joint capsules. As the elastic material of KT pulls and stretches the skin, the movement of skin and underlying superficial fascia covering the muscle may stimulate muscle receptors to perceive potential alterations of length and tension of muscle fibers and other mechanoreceptors to convey information concerning changes in stretch and pressure.[14] Afferent feedback from these skin, muscle, and joint receptors contributes to proprioception at the knee joint.[1] Ultimately, improved proprioceptive feedback as a result of KT would enhance balance ability.[2,6,18] To confirm this hypothesis, our group performed an earlier study[16] demonstrating that the application of KT could indeed improve knee proprioception, as quantified by measures of joint position sense, in healthy athletes with poor proprioceptive status. However, this effect was seen only after physical activity and not in the resting state.[16] Similarly, our present investigation indicated that balance ability was not affected by KT when tested in the resting state. In this regard, our data provide empirical support for the observations by Lins et al.[22] Studying healthy women, these authors observed no alteration in 1-footed static balance after the application of KT. To the best of our knowledge, only 2 groups have examined the effects of KT on balance ability under the concomitant influence of muscle fatigue. Ahn et al[24] found no effect of KT on single-legged static balance after inducing muscle fatigue through repeated isometric contractions of the knee extensors. Similarly, Cavanaugh et al[25] investigated the effect of KT on Y-Balance test performance in healthy, recreationally active participants before and after inducing fatigue through an exhaustive series of unilateral Bulgarian squats and reported no beneficial effects. Yet it should be noted that, in spite of causing substantial muscle fatigue, the short-term exercise interventions performed in both of these studies did not provoke a significant deterioration in balance ability. It appears as if KT positively affects balance ability only when sensorimotor feedback is disturbed, as may be the case after strenuous physical exertion.

Our findings also revealed that the effectiveness of KT in attenuating the exercise-related deterioration in balance ability may depend on the participant's original balance status. Correlational analyses showed a negative relationship ($r = -0.652$, $P = .022$) between our participants' baseline OSI values (as measured without KT and before downhill walking) and the change in OSI after exercise with the use of KT. The balance scores of participants who presented with a high baseline OSI value (ie, below average balance ability) did not deteriorate further after downhill walking when KT was used. Thus, KT effectively mitigated the exercise-related impairment in balance ability in participants whose initial balance status was poorer. This preventive effect of KT application was less pronounced in participants with low baseline OSI value (ie, good initial balance ability). In contrast, no negative correlation was found between baseline OSI and the exercise-related change in OSI when KT was not used. The observed dependency of KT effectiveness agrees with the results of several previous investigations[16,37] of the effect of tape on knee proprioception. Birmingham et al[38] noted that the poorer the proprioceptive ability, the greater the improvement after application of an external knee support, such as a knee brace. In this regard, Perlau et al[39] also hypothesized that afferent stimuli enhanced by such external appliances, although helpful to individuals whose proprioceptive status is classified as poor, can be useless or even detrimental to individuals with better proprioceptive status. Our results indicate that these observations may be extrapolated to measures of balance. Individuals with good balance did not benefit from the external aid provided by KT, whereas the tape may have increased afferent feedback via mechanoreceptors in the skin, muscles, and joint capsule, thereby improving proprioceptive performance and balance ability in athletes with poor balance.

LIMITATIONS

Our study was conducted on healthy students enrolled in a sports science program, which complicates both the extrapolation of results to other cohorts with poorer balance status and the evaluation of the clinical usefulness of the KT application. The latter holds particularly true because the minimal clinically important difference in balance values from the Biodex Balance System is not currently known. Future researchers should investigate the effect of KT on balance ability in individuals with generally poorer balance, such as elderly participants or those with neurologic disease. Furthermore, additional electromyography-based measures (eg, of electromechanical delay) might help to ascertain the degree of physical fatigue provoked by the exercise intervention. Experiments involving longer and more intense physical activities should be performed to test whether the effect of KT on balance ability depends on the degree of exhaustion. It is important to note that balance is influenced not only by muscles acting on the knee but also by those at the ankle and hip joints. In fact, 2 discrete strategies to control postural balance exist[40,41]: the ankle strategy repositions the body's center of mass by moving the body as a single-segment inverted pendulum. The hip strategy, by contrast, incorporates counterphase movements around both the ankle and hip joints to stabilize the center of mass. The taping intervention we used targeted neither the ankle nor the hip muscles. However, earlier authors[42,43] studying the consequences of muscle fatigue on balance indicated that the knee flexors and extensors also have a significant effect on balance performance. Indeed, knee muscle fatigue had an even greater adverse effect on balance ability than did ankle muscle fatigue.[8] Repeated measurements involving computerized posturography might also be biased by learning effects. However, the Biodex Balance System is relatively resistant to improvement through practice.[27] Furthermore, the randomized allocation of participants to taped and untaped testing days can be assumed to have minimized any related bias.

CONCLUSIONS

The deterioration in balance ability caused by eccentric exercise was mitigated by the use of KT in a cohort of healthy young men. The balance-improving effect of KT was more pronounced in participants presenting with below-average balance. Thus, individuals with poor balance status appeared to benefit more from the KT application. Future research will test whether KT application can prevent knee injuries in athletic populations by enhancing balance ability in the fatigued state.

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