Original Articles

The Ergogenic Effect of Elastic Therapeutic Tape on Stride and Step Length in Fatigued Runners

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Abstract

Objective: The purpose of this study was to determine if elastic therapeutic tape placed on anterior lower limbs would affect stride and step length in fatigued runners' gait.

Methods: Forty-two healthy participants were equally divided into a kinesiology tape group (Rocktape) and a no-tape control group. Participants in both groups underwent a baseline running gait test at 6 mph without tape. After this, participants engaged in an exhaustive lower body fatigue protocol until they reached maximal volitional exhaustion. Participants were then randomized to 1 of 2 interventions: (1) Experimental group, which had kinesiology tape placed under tension on the anterior aspect of their lower limbs bilaterally from the upper thigh to just below the patella, or (2) Control group, which did not receive taping. All participants then engaged in a similar 6-mph running gait postanalysis. Participant's gait was analyzed for 90 seconds during each test iteration. Researchers used a 2-way repeated-measures analysis of variance considering fatigue (prefatigue, postfatigue) and group (tape, no-tape) as subject factors.

Results: After the fatigue protocol, the no-tape group demonstrated a significant decrease in step length of 14.2 mm ($P = .041$) and stride length of 29.4 mm ($P = .043$). The kinesiology tape group did not demonstrate a significant decline in these gait parameters.

Conclusions: In this preliminary study, placing elastic therapeutic tape over the anterior lower limbs demonstrated short-term preservation of runner step length and stride length in a fatigued state.

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Introduction

Fatigue occurs with strenuous physical exertion.^{1,2} Physiological fatigue can be caused by central and peripheral mechanisms, with peripheral mechanisms being more critical in motivated athletes.² Four sites that have been shown to be most involved in peripheral fatigue development are impairment of metabolic energy supply, contractile mechanisms, excitation-contraction coupling, and sarcolemma excitability.^{3–5}

Ergogenic aids may be capable of aiding fatigued runners perform. Ergogenics aids may be mechanical (eg, elastic therapeutic tape/kinesiology tape), nutritional, psychologic, and/or pharmacologic.

Elastic therapeutic taping, sometimes referred to as *kinesiology taping*, is a supportive aid that is often used by trainers, therapists, and physicians to address conditions in athletes and patients (eg, one brand is Rocktape). The Rocktape brand has made 4 claims about its product: that it increases kinesthetic awareness through cutaneous afferent stimulation; reduces pain by relieving pressure on pain receptors due to the tape's ability to lift the epidermis; improves fluid dynamics, which reduces edema; and improves the athletes' form.⁶ Furthermore, the company claims that "[R]ocktape can help athletes improve form and decrease fatigue through better blood flow."⁷ However, the impact Rocktape has on athlete fatigue and whether modification in blood flow is the reason remain unproven.

Three systematic reviews have demonstrated there is a lack of high-quality evidence that kinesiology tape can be used to treat musculoskeletal conditions.^{8–10} Limited kinesiology taping studies focusing specifically on athletes with musculoskeletal injuries have been generated.^{11–13} In addition, studies focused on the capability of kinesiology tape to act as an ergogenic aid and improve athletic performance are also limited^{12,14–16}; and thus, further research is warranted because of the popularity of kinesiology tape. Two review articles found that conclusive evidence did not exist to support the use of kinesiology tape at improving athletic performance but that kinesiology tape did not cause any negative effects on performance.^{17,18} One of the 2 articles further went on to point out that there were some small but interesting case studies supporting the use of kinesiology tape for athletes.¹⁸ However, because of the possibility of bias, they suggested that larger, more well-controlled studies were needed.¹⁸

It has been recommended that kinesiology tape should be placed on the posterior and anterior aspect of

the lower limbs for runners.¹⁹ However, the impact of taping the anterior and posterior aspect of the lower limbs, individually or collectively, has not been adequately studied.

To date, there have been no published studies to assess step and stride length in fatigued runners with and without elastic therapeutic tape. Therefore, the purpose of the present study was to determine if step length and stride length would be preserved better in a fatigued state for those who have been taped anteriorly compared with those with no elastic therapeutic tape.

Methods

This study was reviewed and approved by the Texas Chiropractic College Institutional Review Board for human subjects in accordance with the Declaration of Helsinki. All subjects were provided a written and oral explanation of the study procedures prior to participation. This trial was registered with the University hospital Medical Information Network Clinical Trials Registry, trial no. UMIN000014662.

Study Design, Rationale, and Setting

This was a single-blind, randomized, controlled study of the immediate impact that elastic therapeutic had on runner gait in a fatigued state. Forty-two participants were involved in this study (Fig 1). Participants underwent baseline testing of their running gait at 6 mph. This was followed by an Åstrand cycle ergometer maximal test to induce fatigue in all participants. The Åstrand cycle ergometer maximal test is a graded exercise test designed to have participants reach volitional exhaustion. Next, participants were randomized to the (1) Experimental group, which had kinesiology tape placed on the anterior aspect of their lower limbs bilaterally from their upper thigh to just below their patella, or (2) Control, no-tape group. Study participants then engaged in another running gait assessment in a fatigued state at 6 mph. All testing took place in a research laboratory with an ambient room temperature at approximately 74°F, and no music was allowed during testing. Music was not permitted because of literature suggesting it could impact runner cadence.²⁶

Subjects

Asymptomatic college students were recruited for this study. All study applicants provided an informed

Fig 1. Experimental design.

written consent on college-approved documents. They were then screened against inclusion and exclusion criteria (Fig 2). A convenience sample of 42 apparently healthy individuals that met the inclusion/exclusion criteria participated in this study. Each of the 2 study groups was composed of 11 men and 10 women. The kinesiology tape group had the following attributes: 27.1 ± 4.3 years old, 73.0 ± 11.8 kg, 1.74 ± 0.08 m, and 23.9 ± 2.8 body mass index (mean $\pm$ SD). The no-tape control group had the following attributes: 29.0 ± 4.9 years old, 85.4 ± 23.0 kg, 1.75 ± 0.12 m, and 27.5 ± 4.5 body mass index.

Randomization and Blinding

A computer-generated randomized intervention list was created before the study began. That list determined if a participant would be assigned to either study group (experimental vs control). The biomechanics

researcher who analyzed the motion capture data was blinded as to group designation.

Baseline Preparation and Kinematic Recording

Trained research assistants placed 18 silver 19-mm MoCap Solutions (Huntington Beach, CA) reflective markers on the participant's lower body using surgical tape. Reflective markers were placed on the following anatomic landmarks during this study bilaterally: anterior superior iliac spine, posterior superior iliac spine, greater trochanter of the femur, lateral epicondyle of the femur, tibial tuberosity, lateral malleolus, posterior calcaneus, top of the fifth metatarsal head, and top of the first metatarsal head (Fig 3), with a marker set and model as described by Robertson et al.²⁸

Prior to the participant arriving at the laboratory each day, the Vicon (Centennial, CO) system was calibrated as suggested by the manufacturer. During

Inclusion criteria were:
1) they reported no contraindication to running or cycling 2) between the ages of 18-45 3) answering "no" to all exercise contraindication sections on a Physical Activity Readiness Questionnaire (PAR-Q) ²⁷ 4) they provided their informed written consent.
Study participants with any of the following were excluded from the study:
1) any surgery in the past year 2) any broken bones in the past year 3) reported neurologic conditions (multiple sclerosis, myasthenia gravis, diabetes, etc.) 4) reported cardiopulmonary conditions (asthma, congestive heart failure, emphysema, etc.) 5) pregnancy 6) rheumatoid arthritis 7) Down's syndrome 8) known anemia 9) kidney pathology 10) daily pain they rated greater than a 3 on a 1-10 Numeric Rating Scale (NRS)

Fig 2. Study inclusion/exclusion criteria.

the study, participants performed their gait test on the 400 Pro series Keys treadmill (Keys Fitness Products, Inc, Dallas, TX). Participants were instructed to jog at 6 mph for 90 seconds. A research assistant started the treadmill at the same time as another researcher began recording data with the Vicon system. The laboratory's Vicon MX system consisted of 8 infrared Bonita 0.3-megapixel cameras. Kinematic data were recorded at 100 Hz. Immediately after the 90-second recording was made, the initial 15 seconds of each gait trial was clipped from the data to remove any initial steps as the participant became acclimated to the treadmill velocity.

Fatigue Protocol

The fatigue protocol used in this study consisted of having participants engage in an Åstrand cycle ergometer maximal test as described by Heyward²⁹ until they reached volitional exhaustion and had over 8 mmol/L blood lactate, which correlates with maximal to near-maximal exercise effort. Each stage of the exercise test was 2 minutes long. Participants engaged in the cycle ergometer test on the Ergomedic 828E Monark cycle ergometer (Monark AB, Varberg, Sweden). A cycle ergometer was chosen as the instrument

to induce fatigue because it was more likely a foreign form of exercise for most participants in relation to their daily life and thus likely would induce fatigue quickly. The men began pedaling at 2 kp of resistance at 50 rpm. Resistance was increased in 1-kp units at the completion of each stage, as per test protocol. The women began the test at 1-kp resistance at 50 rpm. Their resistance was increased in 0.5-kp units at the completion of each stage, as per test protocol. At the end of each 2-minute stage of the test, participant's heart rate and rating of perceived exertion (RPE) were recorded. Participants wore an RS 300X SD Polar heart rate monitor chest strap (Polar Electro Inc, Lake Success, NY) during the cycle ergometer test. Participants were vocally encouraged to exercise to maximal volitional exhaustion by assistants that were blinded as to which intervention the participant would receive after their cycle ergometer fatigue protocol. The cycle ergometer graded exercise test was concluded when the participant could no longer maintain 50 rpm for 3 seconds straight. Upon test completion, blood lactate was measured from finger prick using the Lactate Plus Blood Lactate monitor (Nova Biomedical, Waltham, MA) and test strips. After the fatigue protocol, participants received an intervention (tape) or not, and then underwent treadmill kinematic testing again within 5 minutes.

Fig 3. Illustration of a study participant and a sample computer model based on silver reflective marker data extraction using the Vicon motion analysis imaging system. Only the left side of the participant's visible markers is labeled to avoid image clutter.

Taping Protocol

During taping, participants were seated on a bench. Knees and hips were flexed to approximately 90°. Researchers used disposable paper towels to wipe sweat from the lower limbs of participants to ensure that the kinesiology tape would be more likely to adhere. Kinesiotape (Rocktape brand) was placed on the anterior aspect of both of their lower limbs from their superior thigh to just inferior to their patella as shown in Fig 4. Three strips of kinesiology tape were used per limb. The tape was stretched to approximately 120% of its initial resting length as an effort was made to pull the patella superiorly. Pressure was applied onto the tape to make it adhere to the skin. Participants were not queried on comfort level of taping during the study. Participants did not have to shave their legs.

Kinematic Post-Data Processing

The data were processed using a customized Matlab script (R2007a; Mathworks, Natick, MA). The kinematic data were analyzed to calculate characteristics of

movement for each participant at baseline and postintervention. In the current study, researchers investigated the changes in the functional active range of motion of the hip angle, knee angle, and ankle angle as a result of the intervention. In addition, stance time, percentage stance time (duration 1 foot was on the ground in relation to the gait cycle), step length, and stride length bilaterally were calculated. Right and left limb individual data were then merged for statistical analysis.

Approximate entropy (ApnEn), a measure of gait variability, was additionally determined for each joint.³⁰ In healthy individuals, there is a certain amount of acceptable variability that represents a normal (healthy) gait pattern. However, highly variable gait patterns are typically indicative of some type of pathology or loss of coordination,³⁰ which may render a person at risk for falling.³¹ Values near “0” represent a stable gait, whereas values near “2” represent a very unstable gait.

Statistical Analysis

To analyze the kinematic data, researchers used a 2-way repeated-measures analysis of variance (ANOVA)

Fig 4. The photographs on the left were taken with a flash to emphasize how the silver reflective markers glow to allow the Vicon motion analysis cameras to track them with 3-dimensional imaging software. The stepwise photographs on the right show how the anterior lower limbs were taped with superior traction on the patella using 3 strips of Rocktape per lower limb. The third strip of tape was a horizontal anchoring strip just below the patella.

considering fatigue (prefatigue, postfatigue) and group (tape, no-tape) as subject factors. The Mauchly test was applied to check the sphericity assumption of the repeated-measures ANOVA, and the Greenhouse-Geisser correction was used during instances of sphericity violation.³² A Bonferroni post hoc test was conducted on statistically significant data among all ANOVAs to determine which condition was significant. The α level of $P < .05$ was considered statistically significant for all tests. Between-groups fatigue protocol data (highest resistance level completed, heart rate, RPE, and blood lactate) were compared using an independent-samples t test (tape, no-tape). The Levene test for equality of variance was used and followed for homogeneity of variance violation. The data (Tables 1–2) were analyzed using SPSS 20.0 (IBM, Armonk, NY).

Results

Table 1 illustrates the grouped attributes of participants after their last successfully completed level of the fatigue protocol. Participants randomized to the experimental group demonstrated a higher level of performance during their exhaustive test than participants in the control group. This was shown by the experimental group completing more stages of the exhaustive test and thus reaching higher mean kilopond cycle ergometer resistance settings. In addition, the experimental group demonstrated statistically significant higher end blood lactate levels than the control group ($P = .046$).

After the fatigue protocol, there was a statistically significant within-group decline in step length ($P = .041$) and stride length ($P = .043$) in the no-tape group (Table 2). There was no statistically significant within-group decline difference in the kinesiology tape group. The effect size for step length between groups was 0.200, and the effect size for stride length was 0.177.

Both of these effect sizes categorically represent small effects between groups.³²

Kinesiology tape placed over the anterior limbs appeared to be protective of natural reductions in step length and stride length in fatigued runners compared with the no-tape control group. Participants in the kinesiology tape group had their step length decrease by 3.2 mm, compared with 14.2 mm for the no-tape control group on average. Similarly, participants in the kinesiology tape group had their stride length decrease by 7.7 mm compared with 29.4 mm for the no-tape control group on average. Thus, participants in the kinesiology tape group lost approximately 22 mm less from their baseline stride length (25.4 mm = 1 in) than the no-tape controls with each gait cycle postfatigue.

Discussion

The implications of this study suggest that elastic therapeutic taping of the anterior thigh aids runner performance in a fatigued state. In this study, step length and stride length were preserved; the duration and full benefit of this protective ability warrant further review.

One hypothesis for the mechanism of action was that the tape might have had a “rubber band”-like action that could help fatigued runners pull their trail lower limb anteriorly due to the elasticity of the tape. Skeletal muscle possesses the property of extensibility (ability to stretch) and elasticity (the ability to recoil).^{20–23} The ability of muscle to stretch and recoil is important to generate force. In a fatigued state, these attributes may be impaired; and deficiencies in running kinematics can occur because of muscle exhaustion.^{24,25}

Existing data support a use for kinesiology taping in reducing edema and helping treat regional swelling^{33,34}; however, there is limited evidence to substantiate its positive impact on various musculoskeletal conditions^{8–10} or its ability to act as an ergogenic aid.^{17,18}

Table 1 Cycle Ergometer Test Results Using Data From the Last Successfully Completed Stage of the Exhaustive Cycle Ergometer Fatigue Protocol

	Kinesiology Tape Group (Experimental Group)	No-Tape Group (Control Group)	<i>P</i>
Highest resistance level completed (kp)	3.6 ± 0.9	3.2 ± 1.1	.424
Heart rate (beats per minute) at last completed level	180.1 ± 11.8	177.9 ± 13.3	.600
Highest reported RPE at last completed level	17.7 ± 2.3	18.2 ± 1.5	.679
End blood lactate (mmol/L)	17.4 ± 3.5	16.2 ± 3.4	.046 *

An independent-samples t test was used to compare between-group data. Data listed as mean ± SD.

RPE, rating of perceived exertion.

* Statistically significant.

Table 2 Running Gait Attribute Data for the Kinesiology Tape and No-Tape Group at 6 mph

	Pre		Post		Mean Diff	LCI	UCI	<i>P</i>
	Mean	SD	Mean	SD				
Experimental group (Kinesiology tape group)								
HpROM (°)	59.1	7.4	58.4	7.2	0.7	−1.56	2.99	.480
KnROM (°)	86.6	10.3	87.7	8.4	−1.1	−5.39	3.09	.542
AnROM (°)	53.5	7.6	53.2	6.2	0.3	−1.63	2.23	.726
STSec (s)	0.43	0.04	0.43	0.03	0.00	−0.0067	0.0091	.737
%ST (%)	56.3	1.0	56.5	0.8	−0.2	−0.71	0.30	.362
StepLen (mm)	681.0	72.7	677.8	60.7	3.2	−11.34	17.78	.617
StriLen (mm)	1416.8	157.7	1409.1	129.2	7.7	−27.48	42.86	.621
HpApnEn	0.28	0.03	0.30	0.04	−0.02	−0.03	0.00	.103
KnApnEn	0.31	0.04	0.31	0.04	0.00	−0.03	0.03	.912
AnApnEn	0.36	0.03	0.34	0.03	0.02	0.00	0.04	.072
Control group (No-tape group)								
HpROM (°)	60.2	8.3	58.6	6.5	1.6	−0.05	3.41	.056
KnROM (°)	84.9	7.1	84.6	7.8	0.3	−1.43	2.14	.659
AnROM (°)	53.6	11.0	54.2	10.4	−0.6	−2.29	1.22	.503
STSec (s)	0.42	0.03	0.41	0.03	0.01	−0.0010	0.012	.066
%ST (%)	56.6	1.0	56.6	1.1	0.0	−0.22	0.21	.968
StepLen (mm)	675.6	55.5	661.4	55.3	14.2	0.74	27.64	.041 *
StriLen (mm)	1430.0	113.2	1400.6	121.0	29.4	1.22	57.69	.043 *
HpApnEn	0.27	0.04	0.27	0.05	0.00	−0.01	0.02	.343
KnApnEn	0.32	0.06	0.32	0.07	0.00	−0.02	0.03	.633
AnApnEn	0.36	0.05	0.36	0.06	0.00	−0.04	0.02	.548

AnApnEn, ankle approximate entropy; *AnROM*, ankle functional range of motion in degrees; *HpApnEn*, hip approximate entropy; *HpROM*, hip functional range of motion in degrees; *KnApnEn*, knee approximate entropy; *KnROM*, knee functional range of motion in degrees; *LCI*, lower 95% confidence interval in relation to mean difference; *StepLen*, step length in millimeters; *StriLen*, stride length in millimeters; *STSec*, stance time in seconds; *UCI*, upper 95% confidence interval in relation to mean difference; *%ST*, stance percentage of gait cycle.

* Statistically significant data.

Research demonstrates that, in a fatigued state, temporarily, muscle activation is reduced,³⁵ muscle reaction time is impaired,³⁶ proprioception declines,³⁷ and there is decreased postural control.^{38,39} The hypothesis of this study was that kinesiology tape would help improve runner performance in a fatigued state by acting like a rubber band when placed on the anterior aspect of the lower limbs to help pull them forwards and aid skeletal muscle's elastic property.^{20–23} Preliminarily, data from this study suggest that kinesiology tape is marginally protective of decreases in step length and stride length among fatigued runners. This study did not test the claim that Rocktape enhances performance in a fatigued state through modification of blood flow.⁷ As a result, this study cannot confirm or deny the validity of that claim.

Research has shown that, with faster running velocities, as seen in short distance sprinting research, small modifications in stride frequency become more critical to overall performance than stride length.^{40–42} Long stride length is associated with faster runner performance in sustained running activities.^{1,40,43,44} In the context of this study's findings, this suggests that kinesiology tape may

be more helpful to runner performance with sustained longer-distance running (eg, 5 km vs 100-m sprint).

In the present study, kinesiology tape placed over the anterior lower limbs of fatigued runners was protective against declines in step length and stride length compared with a no-tape control group. As a result, the implications of this study preliminarily favor that kinesiology tape may modestly benefit athletes that engage in sustained running in a fatigued state.

Therefore, this study's results were supportive of the claim by Rocktape that kinesiology taping can positively impact athletes in a fatigued state. However, this research study did not analyze if modifications in blood flow are the reason for such impact. Further studies are warranted to corroborate the overall findings of this study.

Limitations and Future Studies

Researchers were not able to measure the exact amount of tension in the kinesiology tape that was applied to participants' lower limbs. It is reasonable

that varying levels of tension could have been applied to different participants in this study.

Participants were not asked if they had previously used kinesiology tape in their life prior to entry into this study. It is possible that, if participants had a significant positive reaction to using tape previously, it may have psychologically impacted their performance and central fatigue.

Women were not excluded from recruitment because the timing of the menstrual cycle is not considered a factor that modifies exercise performance.^{45–49}

If additional future data do develop to show a trend like that, then this may be seen as a limitation.

Participants' legs were not shaved. This issue should be addressed in future studies as standardized taping protocols are developed.

Researchers did not recruit a set number of participants based on a power analysis because of this intentionally being a pilot study. Following a post hoc power analysis using G*Power version 3.1.3 (Universität Kiel, Kiel, Germany),^{50,51} researchers determined that study power was 0.5873. This analysis was in accordance with a desired moderate effect size of 0.5, α of .05, 21 participants per group condition compared. In consideration of this analysis, the current study was underpowered and the possibility of type II error exists. Ideally, to have a power of 0.80, researchers would need 34 participants per group. Despite this, it is normal in exercise science research to engage in underpowered studies involving 10 to 20 participants per compared study group to observe data trends.^{52–56}

Lastly, this study did not have a placebo group; and it is feasible that the placebo effect could have impacted study results because only one intervention was used. Future comparative studies should include a placebo group.

The benefit of kinesiology tape at preserving sustained stride length in fatigued runners over longer-duration running warrants additional study because, in this study, participant's gait was only analyzed for 90 seconds during each test iteration. A longer data collection window is needed to clearly determine if the changes observed would be of any consequential benefit to a runner in a race scenario. Future studies should plan to determine the implications of kinesiology tape by engaging in repeated sprint and 1-mile run research comparing participants who have received kinesiology tape to various controls.

Conclusion

The preliminary findings of this experiment showed that placing elastic therapeutic tape on the anterior aspect of the lower limbs from the upper thigh to just below the patella showed short-term protection from declines in step length and stride length of fatigued runners.

Funding Sources and Conflicts of Interest

This research project was supported by a grant from the Rocktape company. No conflicts of interest were reported by the authors for this study.

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