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The effects of ankle braces and taping on lower extremity running kinematics and energy expenditure in healthy, non-injured adults

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ABSTRACT

Ankle braces and taping are commonly used to prevent ankle sprains and allow return to play following injury, however, it is unclear how passive restriction of joint motion may effect running gait kinematics and energy expenditure during exercise. The purpose of this study was to determine the effect of different types of ankle supports on lower extremity kinematics and energy expenditure during continuous running. Thirteen healthy physically active adults ran at self-selected speed on the treadmill for 30 min in four different ankle support conditions: semi-rigid hinged brace, lace-up brace, tape and control. Three-dimensional lower extremity kinematics and energy expenditure were recorded every five minutes. The semi-rigid hinged brace was most effective in restricting frontal plane ankle motion. The lace-up brace and tape restricted sagittal plane ankle motion, while semi-rigid hinged bracing allowed for normal sagittal plane ankle kinematics. Kinematic changes from all three ankle supports were generally persistent through 25–30 min of exercise. Only tape influenced knee kinematics, limiting flexion velocity and flexion-extension excursion. Small but significant increased in energy expenditure was found in tape and semi-rigid hinged brace conditions; however, the increases were not to any practically significant level (< 0.5 kcal/min).

1. Introduction

Lateral ankle sprains are among the most frequent injuries in sports involving running, jumping, and agility activities [1]. These activities potentially force the ankle into excessive inversion and plantar flexion, the most prevalent mechanism of injury for lateral ankle sprains [1,2]. Consequently, the external ankle braces and taping are commonly utilized to prevent ankle injuries and allow return to play following injury by restricting excessive inversion and plantarflexion [1,3]. There are different types of ankle brace, including lace-up type and semi-rigid hinged type and different taping methods, but their main goal is to restrict excessive inversion and plantarflexion range of motion (ROM). However, the reported longevity of ROM restriction varies significantly. Ankle bracing has been reported to restrict inversion and plantarflexion for 20–60 min of activity [2,4–6] while the effect of ankle taping may last for 10–60 min of activity [3,5–10]. This wide range of results could be attributed to the differences in the type of ankle brace, activities, and method. The majority of these findings have been based on non-weight-bearing ROM measures taken before and after activity [2–10], and limited research has examined ROM restriction during weight-bearing activities. Furthermore, to our knowledge, only one study utilized the three-dimensional motion analysis to examine the effects of ankle tape on treadmill running gait but they did not examine ankle braces [11]. This study utilized individuals with chronic ankle instability and noted that the tape resulted in a more neutral ankle ROM during walking and running. Currently, it is unclear how ankle braces and tape influence running gait of individuals without chronic ankle instability. As ankle braces and tape are frequently used for prevention purpose, and running is fundamental to most over-ground sports, their potential influence on running gait is worth examining.

Influences of ankle braces and taping on athletic performance and energy expenditure are also important considerations due to possible alterations of the lower extremity kinetic-chain. No negative influences on various sports specific skills including sprinting, balance and agility exercises have been reported from the use of ankle bracing or taping [3,5,6,12–17]. while vertical jump heights have been reported to

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decrease up to one inch (2.54 cm) [5,6,8,12,14–18]. Very limited information is available regarding the effect of ankle supports on energy expenditure and associated running economy [13,19]. MacKean et al. [13] reported that the energy expenditure while wearing an Aircast Air-Stirrup was significantly higher than tape condition; however, both were not significantly different from a no-tape control condition. Paulson et. al. [19], on the other hand, reported no significant difference between tape and control condition. Changes in mechanical efficiency associated with kinematic alterations at the knee and ankle have been shown to effect running economy [20,21], however, the current evidence regarding the effect of ankle taping and bracing on energy expenditure are inconclusive. Therefore, the purpose of the current study was to examine the effect of different types of ankle braces and taping on lower extremity kinematics and metabolic cost throughout a continuous running activity.

2. Methods

Participants included 13 physically active adults who were free from lower extremity surgery or injury within the past six months (age:24.7 ± 4.2; mass:70.74 ± 9.24 kg; height:1.72 ± 0.08 m, five males:age:24.4 ± 3.4; mass:78.3 ± 4.88 kg; height:1.78 ± 0.02m, eight females:age:24.4 ± 3.6; mass:64.5 ± 6.77 kg; height:1.66 ± 0.06 m). A priori power analysis indicated this sample size as adequate for detecting effect sizes of at least 0.4 (Cohen's d) at an alpha level of 0.05 and a power of 0.80. Each participant completed consent forms approved by the University Committee on Human Studies.

A three-dimensional motion capture system (Vicon MX, Vicon, Inc., Centennial, Colorado, USA) and Vicon software (Nexus and Polygon, Vicon, Inc., Centennial, Colorado, USA) were used to capture, reduce, and analyze kinematic data. Kinematic data were collected using 20 retroreflective markers placed in accordance with a Vicon plug-in-gait marker set [22,23] (Fig. 1).

The location of the malleoli over the ankle support was determined using a custom made template created for each participant on the first day of testing. Template development involved the following: (1) The outline of the shod foot was traced on a blank sheet in a standing position with the involved foot on a 10-in. box and the ankle and knee each at 90°. (2) A standing ruler was placed on the sheet in line with the most prominent point of the malleolus marked on the skin to measure the height. (3) Placement of the standing ruler was marked on the template sheet. (4) The same process was repeated for the medial malleolus. Templates were applied in the same position to determine the locations of the malleoli and in measuring ankle width over the ankle supports during subsequent testing sessions. The medial and lateral markers and the joint widths at knees and ankles were used to calculate the joint centers during the static trials. Data were collected at 240 Hz and smoothed using a fourth-order, low-pass Butterworth filter with a 10 Hz cut off. Global Coordinate System was calibrated prior to each data collection session with the treadmill raised to a 1% grade [24] and static trials were completed on the treadmill prior to running trials. Upon establishment of the joint centers and lower extremity segments, medial markers were removed for the running trials. The joint angles were defined as the angle created by the adjacent segments around the joint center with neutral designated as zero degrees.

A metabolic cart containing an Oxygen Analyzer (Oxygen Analyzer S-3A/I, AEI Technologies, Pittsburgh, PA, USA) and Carbon Dioxide Analyzer (Carbon Dioxide Analyzer CD-3A, AEI Technologies, Pittsburgh, PA, USA) connected with a head support and mouth piece with a 2-way non-rebreather valve (Hans Rudolph, Kansas City, MO, USA) was used to collect metabolic data through standard open-circuit indirect calorimetry procedures. Calibration was performed prior to each trial according to manufacturer's instructions.

Active Ankle T2® (Active Ankle System, Inc., Jeffersonville, IN, USA) was used for a semi-rigid hinged ankle orthosis condition. Active Ankle T2® is a U-shape hinged ankle brace, which consists of medial and lateral ankle semi-rigid stirrups held in place circumferentially by a single horizontal Velcro® strap. The semi-rigid stirrups are composed of

Fig. 1. Plug-in-gait marker set for tape condition.