

Research article

Effects of Preventative Ankle Taping on Planned Change-of-Direction and Reactive Agility Performance and Ankle Muscle Activity in Basketballers

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Abstract

This study investigated the effects of preventative ankle taping on planned change-of-direction and reactive agility performance and peak ankle muscle activity in basketballers. Twenty male basketballers (age = 22.30 ± 3.97 years; height = 1.84 ± 0.09 meters; body mass = 85.96 ± 11.88 kilograms) with no ankle pathologies attended two testing sessions. Within each session, subjects completed six planned and six reactive randomized trials (three to the left and three to the right for each condition) of the Y-shaped agility test, which was recorded by timing lights. In one session, subjects had both ankles un-taped. In the other, both ankles were taped using a modified subtalar sling. Peak tibialis anterior, peroneus longus (PL), peroneus brevis (PB), and soleus muscle activity was recorded for both the inside and outside legs across stance phase during the directional change, which was normalized against 10-meter sprint muscle activity (nEMG). Both the inside and outside cut legs during the change-of-direction step were investigated. Repeated measures ANOVA determined performance time and nEMG differences between un-taped and taped conditions. There were no differences in planned change-of-direction or reactive agility times between the conditions. Inside cut leg PL nEMG decreased when taped for the planned left, reactive left, and reactive right cuts ($p = 0.01$). Outside leg PB and soleus nEMG increased during the taped planned left cut ($p = 0.02$). There were no other nEMG changes during the cuts with taping. Taping did not affect change-of-direction or agility performance. Inside leg PL activity was decreased, possibly due to the tape following the line of muscle action. This may reduce the kinetic demand for the PL during cuts. In conclusion, ankle taping did not significantly affect planned change-of-direction or reactive agility performance, and did not demonstrate large changes in activity of the muscle complex in healthy basketballers.

Key words: Cutting, planned agility, peroneus longus, injury prevention, court sports

Introduction

Basketball players will complete between 40-60 short sprints, over 40 jumps, and approximately 100 high-intensity basketball-specific movements that commonly involve direction changes during a game (Ben Abdelkrim et al., 2007). These actions, especially when landing from a jump, or stopping suddenly to decelerate and change direction, can often place an athlete in vulnerable positions that increase the risk of injury (Carter et al., 2011;

Ellapen et al., 2012). A frequent injury experienced by basketball players is a sprain of the ankle ligaments (Fong et al., 2007). Most ankle sprains involve the lateral ligaments, which can be torn as a result of forced plantar flexion and inversion of the foot, exceeding the physiological range of motion (Bot et al., 2003). Fong et al. (2007) reported that 15.9% of all injuries in basketball players involve the ankle joint, and over 80% of these injuries involve ligament sprains. Depending on the severity of the injury, the loss of playing time can range from several days to several months, and individuals will also have a high risk of re-injury (van Rijn et al., 2008). This places an emphasis on preventative methods that can reduce the incidence of ankle ligament injuries.

Taping or bracing of the ankle is often used by athletes as a way to protect and support this joint (Garrick and Requa, 1973; Olmsted et al., 2004). The use of rigid tape is perhaps the most common method used, with the aim of reducing joint range of motion, such that movements predisposing an athlete to injury can be restricted (Wilkerson, 2002). In addition to reducing injury risk, taping may also influence the activity of the muscles about the ankle joint, including the tibialis anterior (TA), peroneus longus (PL), peroneus brevis (PB), and soleus (SOL), as they are not only involved in movement, but also act as ankle stabilizers (Gribble et al., 2006; Hertel, 2002; Ross et al., 2004; Wilkerson, 2002). There are conflicting results as to the effects that taping may have on muscle activity. For example, research has indicated that ankle taping can increase (Lohrer et al., 1999), have no effect (Gribble et al., 2006; Hopper et al., 1999), or decrease (Alt et al., 1999) peroneal muscle activity during actions involving ankle inversion. There is also a lack of empirical data which has investigated ankle joint muscle activity when the joint is taped during sport-specific movements (Ambegaonkar et al., 2011; Gribble et al., 2006; Hopper et al., 1999), and little analysis of the peak amplitude of the electromyography (EMG) signal as a representation of activity and force (Lockie et al., 2014; Rahnama et al., 2006), particularly within the context of ankle taping, change-of-direction, and agility. Although it is not possible to directly measure muscle force via EMG, there is an association between muscle activity and force, from which force output can be inferred during movement (Kuriki et al., 2012).

This is important, as ankle taping should provide

protection, while not detrimentally affecting athletic movements and performance. However, there have been divergent findings as to whether restricted ankle motion adversely affects an athlete when they need to change direction. Pienkowski et al. (1995) found that ankle bracing did not affect basketballers completing an 18.3-meter (m) shuttle-run, while Verbrugge (1996) determined that taping with the modified Gibney technique did not reduce the time to complete a custom-designed agility course in collegiate male athletes. In contrast, Ambegaonkar et al. (2011) found that ankle taping, with a relatively restrictive closed basket-weave and heel locks technique, did increase the time to complete a right-boomerang run agility test in healthy adults, and Burks et al. (1991) established that 10-yard shuttle run performance decreased in varsity athletes when both ankles were taped. Additionally, there has been relatively little analysis regarding the effects on athletic performance when using strapping tape as an injury prevention measure in healthy basketball players (Ambegaonkar et al., 2011; Gribble et al., 2006). From a preventative perspective, a modification to the subtalar sling method could be beneficial (Sacco et al., 2006; Wilkerson, 1991), as it should reduce frontal plane motion (i.e. inversion and eversion), without providing too much restriction to sagittal plane movements (i.e. plantar and dorsi flexion). This is important, due to the need for the ankle to assist with force attenuation in the sagittal plane and force generation during stance (Bezodis et al., 2008; Hunter et al., 2005). A further issue is that most of the 'agility' tests used when analyzing ankle taping involved efforts that incorporated planned changes of direction. In sports such as basketball, unpredictable movement patterns predominate.

The definition for agility states that it incorporates the initiation of body movement, change of direction, or rapid acceleration or deceleration, which involves a physical and cognitive component, such as recognition of a stimulus, reaction, or execution of a physical response (Sheppard and Young, 2006). Previous research has shown that there is limited commonality between planned change-of-direction movements and reactive agility (Farrow et al., 2005; Lockie et al., 2013; Sheppard et al., 2006; Young et al., 2015), indicating they are two different actions. When investigating rugby union players, Wheeler and Sayers (2010) determined that, when compared to a 45° planned cut, a reactive cut featured less lateral movement in the direction of the final run. As there are differences in the kinematics of reactive agility (Brown et al., 2014; Wheeler and Sayers, 2010), there could also be modifications in the muscle activity between these actions (Lockie et al., 2014; Rand and Ohtsuki, 2000), which could be further affected by the use of rigid tape (Alt et al., 1999). Given that lateral movements can place athletes in compromising positions with respect to injury (Carter et al., 2011; Ellapen et al., 2012), the ankle muscle activity associated with lateral cutting in both planned and reactive conditions must be defined.

If there is a perceived detriment to athletic performance, athletes who have healthy ankles may not use ankle taping (Wilkerson, 1991), which may increase their risk of injury. Therefore, this research will analyze the

effects of ankle taping on planned change-of-direction and reactive agility performance as measured by Y-shaped agility test time, in addition to activity of the muscles about the ankle joint (TA, PL, PB, and SOL) in experienced basketballers. To increase the ecological validity of the study, subjects performed planned and reactive tests on a basketball court, and had both ankles un-taped or taped. To maintain a specific focus for this study, comparisons were only made between the un-taped and taped conditions, and not between legs, or between planned and reactive cutting. It was hypothesized that taping would not affect planned or reactive agility performance, nor would taping affect the muscles responsible for supporting and stabilizing the ankle during cutting movements.

Methods

Subjects

Twenty ($n = 20$) experienced male basketball players (age = 22.30 ± 3.97 years; height = 1.84 ± 0.09 m; body mass = 85.96 ± 11.88 kilograms) from semi-professional basketball squads competing in the highest state-based level of competition in Australia volunteered for the study. Subjects were recruited if they: were over 18 years of age; played basketball at a semi-professional level; were available for all testing sessions; and did not have any existing medical conditions that would compromise participation in the study, with a particular focus on lower-limb pathologies. To provide an emphasis on the effects of preventative ankle taping (as opposed to taping used to treat or support an existing injury), subjects were excluded if they had: an ankle injury in the past year; chronic ankle instability as diagnosed by their personal medical practitioner; any orthopedic condition (e.g. knee sprains or lower-body muscle strains) diagnosed by their personal medical practitioner that caused difficulty running or cutting; or were currently using a prophylactic ankle supports or bracing under the direction of a medical practitioner due to a previous ankle injury (Gribble et al., 2006). The methodology and procedures used in this study were approved by the institutional ethics committee, and conformed to the policy statement with respect to the Declaration of Helsinki. All subjects received a clear explanation of the study, including the risks and benefits of participation, and written informed consent was obtained prior to testing.

Testing procedures

Data was collected over two sessions conducted on an indoor basketball court with a sprung wooden floor. Prior to data collection in the first testing session, the subject's age, height, and body mass was recorded. Height was measured barefoot using a stadiometer (Ecomed Trading, Seven Hills, Australia). Body mass was recorded using digital scales (Tanita Corporation, Tokyo, Japan). All subjects completed the same standardized warm-up before both sessions without any ankle taping. This consisted of five minutes of jogging around the basketball court at a self-selected pace, 10 minutes of dynamic stretching of the lower limbs, and progressive speed runs (two runs each of 50%, 60%, 70%, and 90% of perceived maxi-

mum) over the length of one half of the court (14 m). Immediately after the warm-up, subjects then had the EMG sensors placed on the required muscles (TA, PL, PB, and SOL) on both legs, and their ankles taped depending on the testing session. Following these procedures, the subjects began the testing session.

During the first testing session, subjects completed a 10-m sprint for EMG normalization purposes. For all sessions, subjects were instructed to wear the shoes they normally wear when playing basketball (i.e. high-cut shoes). Although high-cut shoes provide a measure of ankle support, to ensure greater specificity and ecological validity of the testing procedures and applicability to game situations, subjects wore the shoes that they would otherwise use in a game (Lockie et al., 2013; 2014). The order of the testing sessions was randomized amongst the sample with regards to the order of un-taped or taped conditions, planned change-of-direction or reactive agility tasks, and the direction assessed within the agility tasks (i.e. left or right). Before the test trials, two submaximal (~80% of perceived maximum) practice trials were provided for both planned and reactive conditions so as to familiarize subjects with the Y-shaped agility test and light stimulus. The subjects then completed a total of 12 successful trials. This included 6 planned change-of-direction trials (3 trials to the left, and 3 trials to the right), and 6 reactive agility trials (3 trials to the left, and 3 trials to the right). Subjects were tested at the same time of day on both occasions, with 48 hours between sessions.

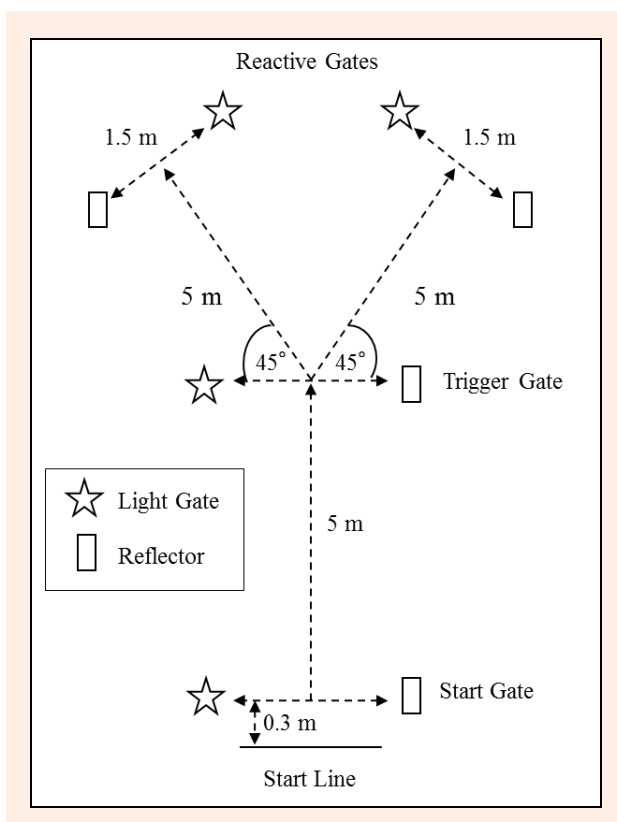


Figure 1. The Y-shaped agility test. Participants ran 5 meters (m) through the start gate to pass the trigger gate, and cut left or right depending on which reactive gate was illuminated.

Y-Shaped agility test

The Y-shaped agility test was used in this study (Figure 1), and this assessment is a valid (Lockie et al., 2013; Oliver and Meyers, 2009) and reliable (Oliver and Meyers, 2009) test of planned change-of-direction and reactive agility performance. Furthermore, the procedures used to test change-of-direction and agility have been established in the literature (Lockie et al., 2013; 2014). A timing lights system (Fusion Sports, Coopers Plains, Australia) was used to record time and set the planned and reactive conditions, which were programmed into the software. Gates were set at a width of 1.5 m, and height of 1.2 m. A goniometer was used to measure the 45° angle from the middle of the trigger gate to the middle of the target gates. The photoelectric cells were positioned on the inside of these gates (Lockie et al., 2013). Subjects began their sprint 30 centimeters (cm) behind the start line and ran maximally through the first two gates. In the planned condition, subjects were told which direction they were to turn. Subjects performed the change-of-direction task as quickly as possible, resulting in an approximate 45° cut, and told not to initiate the change-of-direction until they had passed through the trigger gate. Three successful trials each cutting left and right were completed for the planned conditions. Times were recorded to the nearest 0.001 seconds (s), and averages for the three trials to the left and right were taken. Three minutes recovery was allocated between every trial.

For the reactive conditions, subjects sprinted through the first two gates as per the planned test. However, after passing through the second trigger gate, subjects visually scanned for the flashing gate and once located, performed a 45° cut to sprint through this gate. During reactive trials, subjects performed a split-step after they passed through the trigger gate, which is a very small vertical jump that is a preparatory motion before making a lateral cut (Lockie et al., 2013; 2014; Uzu et al., 2009). Although the split-step was not a part of the planned trials, it was included within the reactive tests to reduce the ability of subjects to pre-guess which gate they thought would illuminate (Lockie et al., 2013; 2014). Furthermore, the action of the split-step is coached in basketballers to encourage a stance that can facilitate lateral movement (Krause et al., 1999; Wissel, 2012). If a subject did pre-guess during a trial (they did not perform a split-step and the trial resembled a planned effort, or the subject initiated movement to the incorrect gate), the trial was discarded and reattempted. Subjects completed six successful reactive trials. The timing lights software was programmed so that three trials to the left and right were completed, but the order was randomized to ensure subjects did not know which direction to turn before the trial. Averages were taken for the three trials to the left and right. As for the planned change-of-direction tests, three minutes recovery was allotted between trials.

Modified subtalar sling taping method

A modification to the subtalar sling method was selected for use in this study on the basis that it would restrict inversion and eversion, without adversely affecting planar and dorsi flexion (Sacco et al., 2006; Wilkerson,

1991). The same researcher applied the tape to all subjects, and this researcher was certified in Advanced Sports Taping through the New South Wales Department of Sport and Recreation in Australia, and had over five years of experience in sports taping. In the taped condition, subjects had both ankles taped, as this commonly occurs in basketball players (Robbins et al., 1995). The modified subtalar sling is shown in Figure 2, and consisted of applying non-elastic tape directly to the skin of the subject's ankles with no shaving or other preparatory measures (Sacco et al., 2006). The tape used was 38-millimeter (mm) rigid sports tape (Beiersdorf Australia Ltd. North Ryde, Australia), and was applied as follows:

- Anchor x 2 (Figure 2A): one anchor was applied approximately 5 cm above the medial and lateral malleoli. The other anchor was applied to the instep (approximate distal head of metatarsals) (Wilkerson, 1991).
- Medio-lateral stirrups x 3 (Figure 2B and 2C): the first stirrup started at the distal anchor medially, passed over the medial malleolus, calcaneus, and lateral malleolus, and attached to the anchor laterally. The next two stirrups were applied 1 cm anterior and 1 cm posterior to the initial stirrup (Wilkerson, 1991). These stirrups were applied with the foot passively held in dorsi flexion and eversion (Sacco et al., 2006).
- Figure 6's/subtalar slings x 2 (Figure 2D and 2E): one sling was applied to the plantar surface of the foot, passing laterally and diagonally around the lateral malleolus at an approximate 45° angle, before attaching medially to the superior anchor (Sacco et al., 2006; Wilkerson, 1991). The second subtalar sling was applied in the same orientation, 1 cm distal to the first sling (Wilkerson, 1991). Both slings were applied with the foot held passively in a dorsi flexed and everted position (Sacco et al., 2006; Wilkerson, 1991).
- Horse-shoe stirrup lock (Figure 2E): applied perpendicular to the stirrups, originating from stirrups medially to laterally across the posterior surface of the foot, and finishing at lateral stirrup slightly distal to the malleoli (Wilkerson, 1991).
- Anchor lock x 2 (Figure 2F): applied on top of the original anchors to secure the tape (Sacco et al., 2006; Wilkerson, 1991).

EMG preparation and data collection

The procedures used for the EMG data collection and analysis have been established in the literature (Lockie et al., 2014). A wireless surface EMG system (Delsys Trigno, Boston, USA), which allowed free movement for the subjects, assessed muscle activity during the tests. This system has been found to record reliable data in lower-body muscles (Keshwani and McLean, 2012; Norcross et al., 2010; Scott et al., 2014). The dimensions for each EMG unit were 27 x 37 x 15 mm, weighed less than 15 grams, while the four-contact fixed inter-electrode distance on each sensor were 1 cm.

The activity of the TA, PL, PB, and SOL were analyzed because of their importance to ankle function during gait. The TA was included for its role as a primary dorsi flexor of the foot (Ebigh et al., 1997). The PL and PB

were investigated as they are the primary everters of the foot (Hertel, 2002). The SOL was analyzed for its action in decelerating the rear-foot at ground contact, controlling ankle inversion, as well as its role in plantar flexion (Brown et al., 2004). Both legs were assessed simultaneously during the Y-shaped agility test as the Delsys Trigno EMG system had the requisite available sensors, and these legs were defined as the inside and outside cut legs (Lockie et al., 2014). The process for defining each leg will be described.

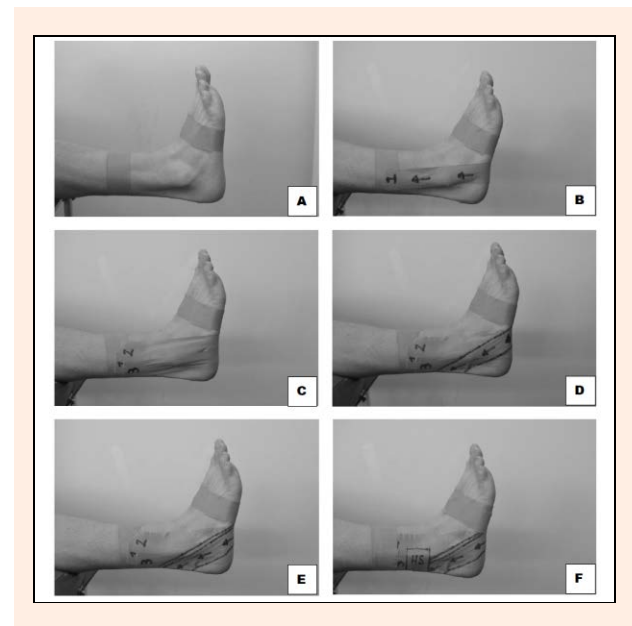


Figure 2. Subtalar sling taping method applied to both ankles during taping condition: **A)** base anchors; **B)** single medio-lateral stirrup; **C)** additional medio-lateral stirrups (three in total); **D)** single subtalar sling (medio-lateral); **E)** additional subtalar sling (medio-lateral), with horse-shoe stirrup lock; **F)** anchor-locks.

The skin was prepared by shaving, abrading, and wiping with alcohol to remove debris. Double-sided, hypoallergenic adhesive tape (Delsys, Boston, USA) was used to attach the electrodes to the skin. The sensors were placed upon each muscle with respect to muscle fiber direction according to standard procedures (Murley et al., 2010; Ricard and Sherwood, 2000; Sacco et al., 2009). The subject's shank length was measured using a Lufkin executive thin-line tape measure (Apex Tool Group, Cleveland, USA), from the distal head of the fibula to the lateral epicondyle of the ankle, and landmarks were determined by palpation. From this, the shank was divided into thirds, and these lines were marked on the leg with a wax pencil (Paul Duval Pty. Ltd., Tullamarine, Australia), before the leg was palpated for the target muscles.

TA sensor placement was on the anterior proximal third of the shank, slightly lateral to the tibial spine, on the muscle belly of TA. PL sensor placement was on the proximal third of the shank lateral to the placement of the TA sensor on the line of PL. PB sensor placement was on the distal third of the shank, anterior to the line of the PL. SOL sensor placement was on the posterior-lateral distal thirds of the shank, anterior to the muscle line of the lat-

eral gastrocnemius, but posterior to the PL. Two accelerometers (Delsys, Boston, USA) were placed on the lateral border of the subject's shoes to record foot-strike. Even though the movements assessed in this study generally involved fore-foot landings, standard procedure for the Delsys Trigno system was to place the accelerometers on the lateral border of the heels. Figure 3 displays the sensor and accelerometer placement positions.

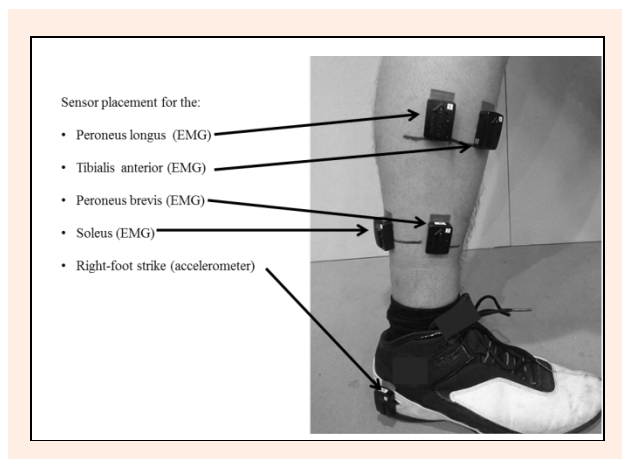


Figure 3. Placement of electromyography (EMG) sensors for capture of activity of the tibialis anterior, peroneus longus, peroneus brevis and soleus, and accelerometer sensor for foot-strike recording for the right leg.

EMG data analysis

EMGworks4 software (Delsys, Boston, USA), was used to analyze and record data for all trials. Data were sampled at 1000 Hertz (Hz), passed through a differential amplifier at a gain of 300, and band-pass filtered (4th order Butterworth) (Norcross et al., 2010; Scott et al., 2014), at 20-450 Hz (Lockie et al., 2014). To define each ground contact for the accelerometers, a foot-strike filter limit of 0.8 times gravity was used according to standard procedures for EMGworks4. Foot-strikes below this threshold were excluded (Lockie et al., 2014; Vaes et al., 2002). 10-m sprint performance was used to normalize EMG data, which is a method used in previous research (Ball and Scurr, 2009; Lockie et al., 2014). This provided a baseline with respect to the change-of-direction and agility tests, and was completed following the warm-up in the first testing session. Timing light gates were positioned at 0 m and 10 m, at a width of 1.5 m and height of 1.2 m. Subjects started 30 cm behind the first gate, sprinted maximally through both gates, and completed three trials. The fastest trial was used for normalization (Ball and Scurr, 2009; Lockie et al., 2014). Activity from all the target muscles was recorded throughout the 10-m sprints.

EMG data from the fastest 10-m sprint time was trimmed to exclude any data collected after the completion of the sprint. Each stance phase (foot-strike to toe-off) within the 10-m sprint was defined from the vertical and anteroposterior plane of the acceleration waveform of the foot (Evans et al., 1991; Lockie et al., 2014), in accordance with the set filter limit (Lockie et al., 2014; Vaes et al., 2002). The EMG data was full-wave rectified, and smoothed via a zero-lag moving window. The data was also passed with a sliding RMS filter (window length =

0.125 s; overlap window = 0.065 s) for the 10-m sprint data. The peak amplitude of the RMS during each stance for each muscle was averaged within the 10-m sprint, and this provided the basis for normalization (Ball and Scurr, 2009; Lockie et al., 2014).

With regards to the analysis of planned change-of-direction and reactive agility, the EMG data from all trials for each condition (un-taped and taped; left and right planned and reactive cuts) was analyzed and averaged within the two contacts for the change-of-direction step. This denoted the inside and outside cut legs depending on the direction. The inside leg was the leg closest to the target direction; the outside leg was the leg furthest away from the target direction. The data recorded by the EMG system was matched to that of the timing lights, so that all data recorded within the time taken to initiate the trigger gate (0-5 m time from the start gate to the trigger gate; Figure 1) was eliminated and the change-of-direction step for each trial could be identified. As for the 10-m sprint, within the change-of-direction step the vertical and anteroposterior acceleration waveforms above the accelerometer filter limit defined foot-strike and toe-off for each leg. Depending on the trial, this was either a left foot-to-right foot contact, or right foot-to-left foot contact. For the planned trials, the first two contacts (foot-strike to toe-off) following the time when the subject passed through the trigger gate defined the change-of-direction step. In the reactive conditions, the first two contacts following the split-step defined the change-of-direction step. These could be identified from the accelerometer and EMG data associated with the cut (Lockie et al., 2014).

For each trial, peak muscle activity within the two contacts for the change-of-direction step, which denoted the inside and outside cut legs depending on the direction, were analyzed. This was adapted from previous research that has investigated peak EMG as the primary measure of muscle activity (Castro et al., 2013; Gribble et al., 2006; Lockie et al., 2014). Concentric or eccentric contractions were not defined, but rather the peak amplitude of the muscle activity during stance. The calculation of the peak EMG occurred within the period from the initiation of foot-strike to the end of toe-off (Gribble et al., 2006; Lockie et al., 2014). The EMG data was treated as per the previously stated procedures, before being normalized to the 10-m RMS sprint data via the amplitude analysis function of the EMGworks4 software. The RMS amplitude produced by a muscle during the change-of-direction step was calculated relative to that recorded during the 10-m sprint. The peak normalized EMG (nEMG) was expressed as a percentage and derived for each muscle during the cut. EMG traces of the activity for each muscle during the change-of-direction were also descriptively analyzed with regards to the pattern of activity during stance.

Statistical analysis

All statistics were computed using the Statistics Package for Social Sciences Version 20.0 (IBM, Armonk, United States of America). Descriptive statistics (mean \pm standard deviation; 95% confidence intervals) were used to profile each parameter. A repeated measures analysis of

Table 1. Comparison of un-taped and taped ankle conditions in Y-shaped agility test performance times mean (\pm standard deviation) [95% confidence intervals]; planned left, planned right, reactive left, reactive right) for experienced basketball players (n = 20). s = seconds; p = significance; d = effect size.

	Planned Change-of-Direction					Reactive Agility				
	Un-Taped (s)	Taped (s)	p	d	d Strength	Un-Taped (s)	Taped (s)	p	d	d Strength
Left	1.95 (.09) [1.90-1.99]	1.96 (.13) [1.90-2.02]	.67	.09	Small	2.77 (.17) [2.69-2.84]	2.72 (.12) [2.66-2.78]	.15	.34	Small
Right	1.98 (.16) [1.90-2.05]	1.95 (.15) [1.88-2.03]	.24	.19	Small	2.75 (.19) [2.67-2.84]	2.75 (.17) [2.67-2.83]	.97	<.01	Small

variance (ANOVA) was utilized to compare differences in time for the planned change-of-direction and reactive agility tests to the left and right, and nEMG for each muscle during the change-of-direction step. This type of analysis was conducted to minimize the chances of making Type I errors, and the criterion for significance was set as $p < 0.05$. The within-subjects measure (i.e. ankle taping) represented the un-taped and taped conditions. As only two repeated measures were employed, the assumption of sphericity, determined by Mauchly’s test of sphericity, was not applicable (Spinks et al., 2007; Vincent, 1995). Other repeated measures ANOVA assumptions, such as the individuals representing a random sample of healthy basketball players, and a normal distribution of data, were considered (Vincent, 1995). Stem-and-leaf plots were used to ascertain whether there were any outliers in the data for each variable. Any outliers were treated via a winsorization method (Callaghan et al., 2014; Lien and Balakrishnan, 2005). Stem-and-leaf (Mertler and Vannatta, 2013; Williamson et al., 1989) and Q-Q plots (Andersen et al., 2014; Lockie et al., 2012; Panousis et al., 2007) were then checked again, and confirmed the normal distribution of data for the analyzed variables. Each leg was analyzed individually, and as stated, comparisons were only made between the independent variable of the un-taped and taped conditions. Effect sizes (Cohen’s *d*) were also calculated by dividing the means by the pooled standard deviations (Cohen, 1988). Following guidelines set by Cohen (1988), *d* of 0.50 or lower was considered a small effect; 0.51 to 0.80 a moderate effect; and 0.81 and above a large effect.

Results

The results showed no significant differences between Y-shaped agility test time between the un-taped and taped conditions for either the planned or reactive tests (Table 1). Table 2 displays the nEMG data for the muscles of the

left leg when it was the inside and outside leg of the planned cuts in the Y-shaped agility test. Table 3 shows the same data for the right leg. The left leg PL had a significant 39% reduction in nEMG during the taped condition. There were no other significant changes in nEMG for the inside leg of the planned cut. For the left leg when it was the outside cut leg (i.e. cutting towards the right), PB nEMG significantly increased by 33% during the taped condition. There was also a 23% increase in nEMG SOL activity for the taped condition, with a small effect ($d = 0.46$). There were no further observed changes to outside cut leg nEMG for the left leg, and no significant nEMG changes for the right leg.

Table 4 displays the nEMG data for the muscles of left leg during the reactive cuts, while the right leg nEMG reactive cut data is presented in Table 5. The nEMG for the left leg PL significantly decreased by 24% during the taped condition when it was the inside leg. This was also true for the right inside leg PL, which significantly decreased nEMG by 38% when the ankle was taped. There were no significant changes to the inside leg TA, PB, or SOL for either leg. There were also no significant nEMG changes to any of the muscles between un-taped and taped conditions for the outside cutting leg during reactive conditions (Table 3). Although the change was not significant, there was a small effect ($d = 0.42$) for the 21% decrease in outside, right leg PL activity.

There appeared to be minimal change in the typical pattern of activity during the change-of-direction step when the ankles were taped for subjects in either the planned or reactive conditions. As an example, Figure 4 displays the nEMG traces for a typical subject for both legs when they were the inside leg of planned and reactive cuts. There were no real differences in the timing and pattern of muscle activity during the cut in the un-taped or taped conditions. The same was true for the outside leg (Figure 5).

Table 2. Comparison of un-taped and taped ankle conditions for peak normalised activity mean (\pm standard deviation) [95% confidence intervals] in the tibialis anterior (TA), peroneus longus (PL), peroneus brevis (PB), and soleus (SOL) for the left leg when it was either the inside or outside leg of a planned cut in the Y-shaped agility test in experienced basketball players (n = 20). % = normalised electromyography measured as a percentage; p = significance; d = effect size.

	Inside Cut Leg					Outside Cut Leg				
	Un-Taped (%)	Taped (%)	p	d	d Strength	Un-Taped (%)	Taped (%)	p	d	d Strength
TA	74.14 (34.69) [57.91-90.38]	81.30 (36.67) [64.14-98.46]	.42	.20	Small	74.45 (38.46) [56.45-92.45]	82.27 (34.59) [66.08-98.46]	.33	.21	Small
PL	100.96 (46.37) [79.26-122.67]	62.00 (30.71) [47.63-76.37]	.01*	.99	Large	71.89 (26.64) [59.43-84.36]	74.16 (28.73) [60.71-87.60]	.71	.08	Small
PB	88.74 (39.60) [70.20-107.27]	100.70 (53.16) [75.82-125.58]	.32	.26	Small	84.40 (24.68) [72.84-95.95]	112.02 (46.62) [90.20-133.84]	.02*	.74	Moderate
SOL	98.85 (45.31) [77.65-120.06]	91.18 (47.53) [68.93-113.43]	.48	.17	Small	81.29 (30.05) [67.23-95.36]	100.31 (50.86) [76.51-124.12]	.03*	.46	Small

* Significant difference ($p < 0.05$) between un-taped and taped conditions.

Table 3. Comparison of un-taped and taped ankle conditions for peak normalised activity mean (\pm standard deviation) [95% confidence intervals] in the tibialis anterior (TA), peroneus longus (PL), peroneus brevis (PB), and soleus (SOL) for the right leg when it was either the inside or outside leg of a planned cut in the Y-shaped agility test in experienced basketball players ($n = 20$). % = normalised electromyography measured as a percentage; p = significance; d = effect size.

	Inside Cut Leg					Outside Cut Leg				
	Un-Taped (%)	Taped (%)	p	d	d Strength	Un-Taped (%)	Taped (%)	p	d	d Strength
TA	70.43 (15.78) [63.05-77.82]	74.74 (25.57) [62.77-86.70]	.44	.20	Small	74.51 (15.60) [67.20-81.81]	74.52 (24.69) [62.97-86.08]	1.00	>.01	Small
PL	86.41 (43.69) [65.96-106.86]	67.89 (33.78) [52.08-83.70]	.08	.47	Large	81.53 (28.26) [68.30-87.76]	70.37 (33.30) [54.79-94.75]	.21	.36	Small
PB	90.33 (40.69) [71.28-109.37]	110.11 (58.57) [82.69-137.52]	.10	.39	Small	103.04 (49.60) [79.83-126.26]	100.04 (55.15) [74.23-125.85]	.76	.06	Small
SOL	101.61 (51.76) [77.38-125.83]	111.47 (51.25) [87.48-135.45]	.43	.19	Small	96.88 (37.28) [79.43-114.32]	94.19 (43.35) [73.90-114.48]	.80	.07	Small

Table 4. Comparison of un-taped and taped ankle conditions for peak normalised activity mean (\pm standard deviation) [95% confidence intervals] in the tibialis anterior (TA), peroneus longus (PL), peroneus brevis (PB), and soleus (SOL) for the left leg when it was either the inside or outside leg of a reactive cut in the Y-shaped agility test in experienced basketball players ($n = 20$). % = normalised electromyography measured as a percentage; p = significance; d = effect size.

	Inside Cut Leg					Outside Cut Leg				
	Un-Taped (%)	Taped (%)	p	d	d Strength	Un-Taped (%)	Taped (%)	p	d	d Strength
TA	90.01 (46.71) [68.15-111.87]	81.13 (39.71) [62.55-99.72]	.47	.20	Small	90.75 (33.81) [74.93-106.57]	90.67 (42.21) [70.91-110.42]	1.00	>.01	Small
PL	88.98 (36.95) [71.69-106.28]	67.80 (25.60) [55.82-79.78]	.01*	.67	Moderate	82.65 (25.55) [70.69-94.61]	72.23 (22.16) [61.86-82.60]	.13	.44	Small
PB	96.31 (35.24) [79.82-112.80]	93.72 (22.22) [83.32-104.12]	.68	.09	Small	106.77 (41.08) [87.54-125.99]	111.08 (50.27) [87.55-134.61]	.76	.05	Small
SOL	92.41 (41.70) [72.89-111.92]	94.95 (54.14) [69.61-120.29]	.78	.05	Small	98.75 (35.21) [82.27-115.23]	102.47 (47.75) [80.12-124.81]	.61	.09	Small

* Significant difference ($p < 0.05$) between un-taped and taped conditions.

Table 5. Comparison of un-taped and taped ankle conditions for peak normalised activity mean (\pm standard deviation) [95% confidence intervals] in the tibialis anterior (TA), peroneus longus (PL), peroneus brevis (PB), and soleus (SOL) for the right leg when it was either the inside or outside leg of a reactive cut in the Y-shaped agility test in experienced basketball players ($n = 20$). % = normalised electromyography measured as a percentage; p = significance; d = effect size.

	Inside Cut Leg					Outside Cut Leg				
	Un-Taped (%)	Taped (%)	p	d	d Strength	Un-Taped (%)	Taped (%)	p	d	d Strength
TA	79.49 (24.67) [67.95-91.04]	78.96 (18.80) [70.16-87.76]	.93	.02	Small	76.26 (20.74) [66.55-85.96]	72.72 (24.50) [61.25-84.18]	.55	.16	Small
PL	113.65 (64.31) [83.55-143.75]	70.36 (8.05) [53.52-87.20]	.01*	.94	Large	102.08 (55.39) [76.15-128.00]	80.84 (45.43) [59.58-102.10]	.09	.42	Small
PB	91.58 (44.30) [70.84-112.31]	100.86 (67.61) [69.22-132.51]	.51	.16	Small	91.80 (44.55) [70.95-112.65]	93.74 (59.72) [65.79-121.69]	.87	.04	Small
SOL	88.32 (34.86) [72.01-104.64]	95.20 (42.82) [75.16-115.24]	.54	.18	Small	101.12 (50.52) [77.48-124.77]	110.44 (49.41) [87.32-133.56]	.46	.19	Small

* Significant difference ($p < 0.05$) between un-taped and taped conditions.

Discussion

Ankle taping is often employed by athletic trainers in order to prevent the incidence and severity of lateral ankle sprains. A reason players with previously uninjured ankles may avoid using ankle taping for injury prevention is because of a believed detriment to athletic performance (Wilkerson, 1991). However, the results from the current study reaffirm findings from Ambegaonkar et al. (2011) and Verbrugge (1996) by demonstrating that ankle taping did not affect planned change-of-direction performance as measured by the total Y-shaped agility test (Table 1). A unique aim of this research was to document whether preventative ankle taping affected reactive agility performance, which it did not (Table 1). This may be related to the taping method used, which was chosen on the basis that it should have little impairment on sagittal plane ankle movements. However, more recent research has

acknowledged the value of measuring change-of-direction velocity immediately following a cut (Spiteri et al., 2013; 2014; 2015), or time over short distances (e.g. 2 m or less) (Sayers, 2015), as opposed to total test time. Future research should document whether ankle taping affects change-of-direction velocity under planned and reactive conditions. Nevertheless, the current study suggests that athletic trainers could use the modified subtalar sling with the knowledge that both planned change-of-direction and reactive agility performance should be relatively unaffected in their players.

The PL and PB are the primary evertors of the ankle-foot complex, providing dynamic stability to the ankle, while the tendons for these muscles support the lateral ankle ligaments (Murley et al., 2009; Wilkerson, 2002). In the planned conditions, there was a 39% decrease in nEMG for the PL during the taped condition when the left leg was the inside leg of the cut (Table 2).

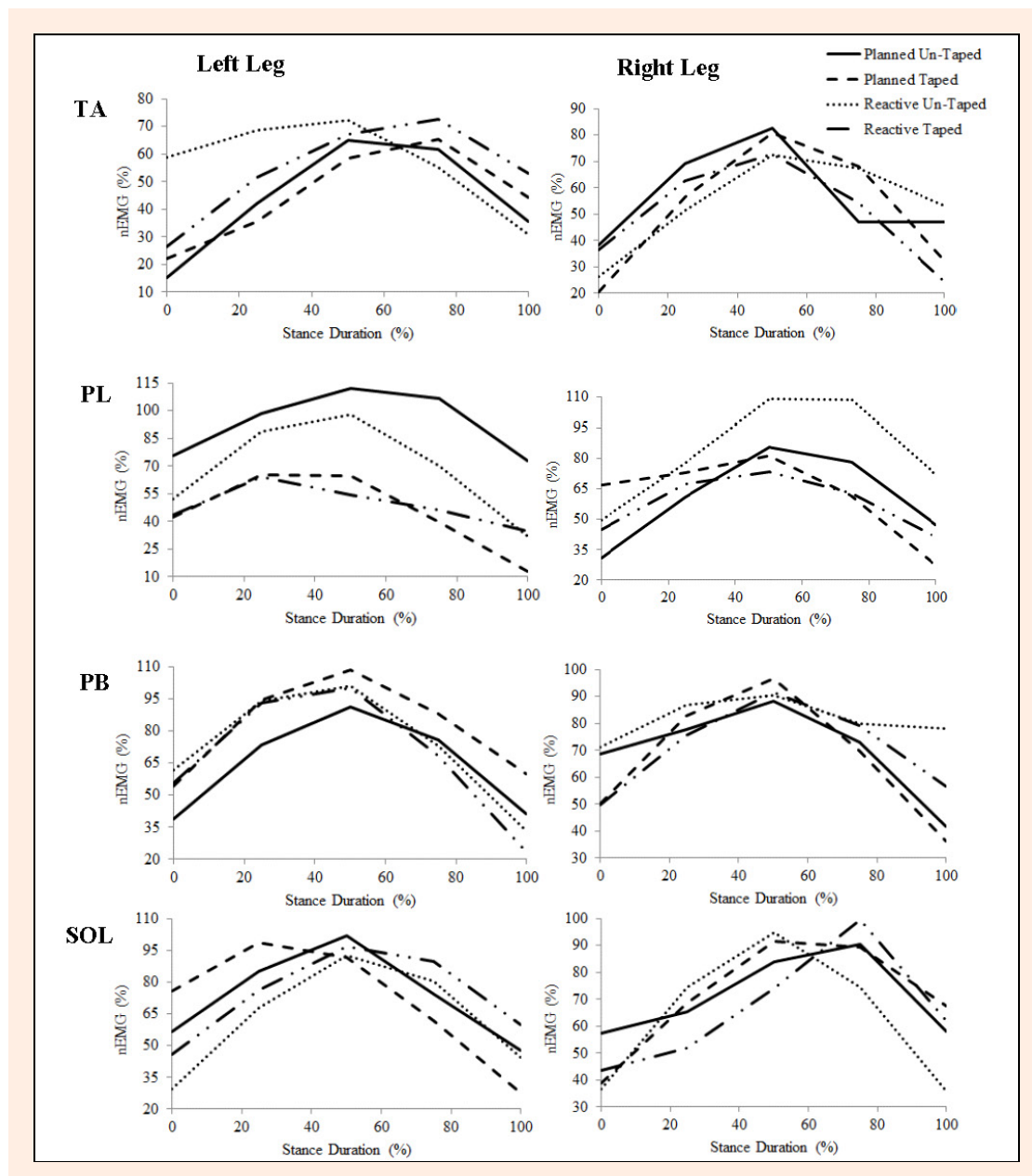


Figure 4. Normalized electromyography (nEMG) for the tibialis anterior (TA), peroneus longus (PL), peroneus brevis (PB) and soleus (SOL) in the left and right legs when they were the inside leg during the change-of-direction step in the Y-shaped agility in a typical basketball player.

This reduction may be the result of the modified subtalar sling restricting rear-foot supination by mechanically holding the foot in a greater degree of eversion. Indeed, previous research suggests that this type of taping method may guard against excessive rear-foot supination, which can be a pre-cursor to an inversion sprain (Sacco et al., 2006; Wilkerson, 1991). It must be acknowledged, however, that a reduction in PL peak activity was only seen in cuts to the left, and there were no changes to the peroneal activity for the inside, right leg during planned cuts. This suggests that for the most part, ankle taping will not affect normal PL function during cutting. Nonetheless, any reduction in PL activity could relate to a reduction in kinetic demand for this muscle (Murley et al., 2009; 2010).

During the reactive agility taped conditions, the inside leg nEMG of the PL was reduced by 24% in the left, and 38% in the right leg (Tables 4 and 5; Figure 4). Alt et al. (1999) found that ankle taping produced 18% less peroneal activity during a simulated ankle inversion in healthy males, due to a decrease in inversion velocity. The lower nEMG PL activity observed suggests that the taping may enhance stability by restricting rear-foot supination and supporting the action of the PL, and this may reduce reliance on this muscle during the cut. A benefit of this is that if there is less muscle activity associated with footfall during gait, there may also be reduced subsequent fatigue (Cheung and Ng, 2010). Fatigue of the PL may augment rear-foot pronation with exercise, leading to an increased risk of inversion injury (Cheung and Ng, 2010).

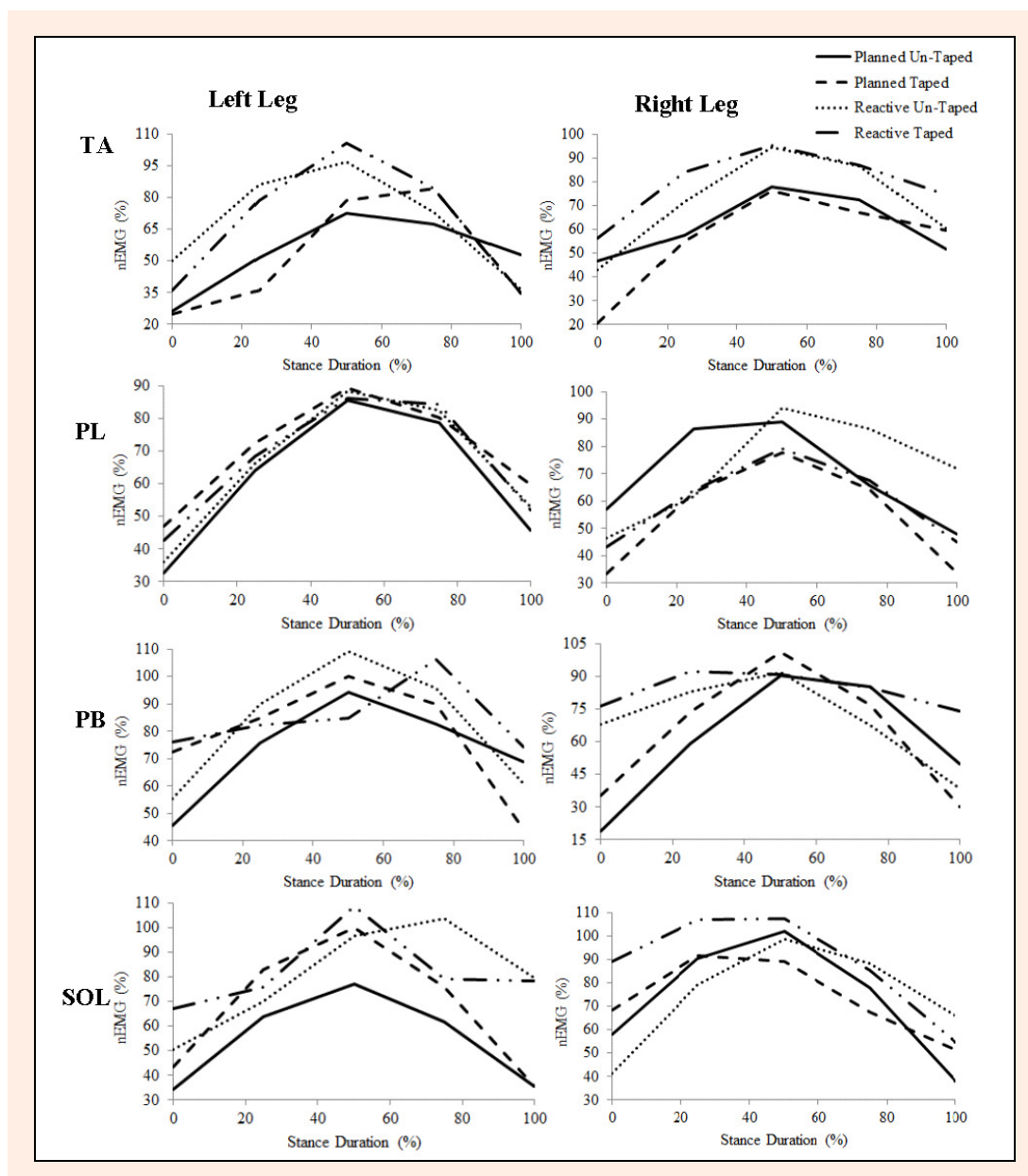


Figure 5. Normalized electromyography (nEMG) for the tibialis anterior (TA), peroneus longus (PL), peroneus brevis (PB) and soleus (SOL) in the left and right legs when they were the outside leg during the change-of-direction step in the Y-shaped agility in a typical basketball player.

The taping method used in this study may provide a potential fatigue-reducing component, particularly if the taping procedure could elicit this change in PL activity consistently throughout the duration of a basketball game for the inside leg of directional cuts. However, this would need to be confirmed through further research.

There were no significant changes to PL nEMG in the taped condition for the outside leg in all cuts (Tables 2-5; Figures 4 and 5). Previous research has shown that taping or bracing has no effect on peak PL activity in movements causing ankle inversion (Cordova et al., 1998; Gribble et al., 2006). During a cut such as that featured in the Y-shaped agility test, the outside foot is placed further away from the midline of the body (Rand and Ohtsuki, 2000; Wheeler and Sayers, 2010), and the ankle will adduct and invert during the contact phase of the sidestep (McLean et al., 2004). This places a greater demand on

the PL, as one of the prime responsibilities for this muscle is to control these movements (Gribble et al., 2006; McLean et al., 2004; Neptune et al., 1999). Potentially, even with ankle taping and the consequent joint restriction (Sacco et al., 2006; Wilkerson, 1991), the demand placed on the PL ensures that there will generally not be a significant drop in its activity. Moreover, these results suggest that even with preventative taping, outside leg PL nEMG remained consistent during a planned or reactive cut.

There was one significant change in PB nEMG activity with taping, with a 33% increase for the outside leg in the planned cut (Table 2). Ashton-Miller et al. (1996) has stated that strong, fully activated ankle evertors, including the PB, provides protection for the ankle when it is inverted, which would potentially occur during a 45° planned cut. However, given that the PL and PB will generally act synergistically (Konradsen et al., 1997), it is

somewhat surprising that in the cut where there was a change in PB nEMG, there was not also a change in PL nEMG (Table 2). Karlsson and Andreasson (1992) simulated ankle inversion injuries using a trapdoor in otherwise healthy individuals with lateral ankle instability, and found that taping increased PL reaction time more than PB. In certain situations, the PL may respond differently to taping than the PB, which could provide some indication why there was a change in PB nEMG, but not for the PL. Nevertheless, there were no other significant changes to PB nEMG activity with taping (Tables 2-5; Figures 4 and 5). The findings from the current study suggest that the modified subtalar sling will not change the inherent activity of the PB during planned change-of-direction and reactive agility tasks.

The SOL plays an important role at take-off from stance (Wilkerson, 1991, 2002), and the eccentric action of this muscle decelerates the rear-foot upon landing (Ross et al., 2004). There was a significant increase in the nEMG of the SOL during the taped condition for the left ankle of the outside leg in a planned right cut (Table 2). This finding may be associated with a need for the ankle to attenuate the higher lateral forces involved in a 45° planned cut (Wheeler and Sayers, 2010). Wilkerson (1991) states that a stable subtalar joint is essential for transfer of force from the SOL at toe-off, and this could have been facilitated by the modified subtalar sling taping method. However, there were no other significant changes in the SOL nEMG during the change-of-direction step for the outside leg of the planned cut to the left, or for either reactive cut (Tables 2-5; Figures 4 and 5). These results suggest that the SOL was generally not affected by the taping method, and normal function during cutting maneuvers was likely maintained.

During a cut, TA activity is constant throughout the movement to dorsi flex the foot before impact, and provide ankle joint stability during the stance and propulsion phases (Neptune et al., 1999). As a result, the TA can act as a dynamic protector against inversion ankle injuries (Hertel, 2002). Depending on the taping method used, dorsi flexion can be reduced (Lohrer et al., 1999), which may change the nEMG of the TA. Due to the importance of ankle dorsi flexion within the gait pattern, it is important that ankle function in the sagittal plane is not restricted by preventative ankle taping in healthy athletes. The results from this research suggest that this was the case for the modified subtalar sling, as there were no significant changes to the TA nEMG in the planned or reactive change-of-direction step (Tables 2-5; Figures 4 and 5). Given that the Y-shaped agility test times were not inhibited by taping (Table 1), in combination with no change in TA activity across conditions, it is likely that excessive dorsi flexion restriction was not caused by the modified subtalar sling in basketball players. In line with previous research (Sacco et al., 2006; Wilkerson, 1991), these results suggest that the taping method likely reduced frontal plane motion (inversion and eversion), without overly restricting sagittal plane movements (plantar and dorsi flexion).

There were certain limitations for this study. There was no analysis of technique or stance kinetics during the

cuts with ankle taping. This resulted from attempts to increase the ecological validity of the study by assessing the muscle activity of both legs and by conducting analysis on a basketball court, which precluded the use of motion capture or force plates. It would be of benefit to conduct a detailed biomechanical analysis of the effects of ankle taping on planned and reactive cutting in basketballers. Additionally, it would also be beneficial to measure whether ankle taping influences velocity immediately out of a cut, as this can provide a different measure of change-of-direction and agility performance than total test time (Sayers, 2015; Spiteri et al., 2013; 2014; 2015), such as that for the Y-shaped agility test. The strapping tape applied to each subject may have varied between testing occasions. However, the same, trained researcher did apply tape for all subjects to ensure greater consistency. Comparisons were not made between legs, nor were any potential differences between planned and reactive agility explored, which could be an avenue of further study. Additionally, only peak EMG was used as a measure of muscle activity, although this has been used in previous research (Castro et al., 2013; Gribble et al., 2006; Lockie et al., 2014). EMG can also vary depending on the time of day a subject is assessed (Sedliak et al., 2011; Yang and Winter, 1983), although the researchers attempted to minimize these effects by being consistent about when the subjects were tested (i.e. the same time of day). Ankle taping may influence the timing of a muscle's peak activity (muscle latency) during a planned or reactive cut, and this should be investigated further. The influence of prolonged use of ankle taping on agility and ankle muscle activity, for example, the duration of a basketball game, was also not investigated in this study and should be analyzed in greater detail.

Conclusion

The findings from this study document that ankle taping using the modified subtalar sling will not affect planned or reactive agility as measured by the Y-shaped agility test in healthy male basketball players. This taping method also caused a decrease in PL activity for the inside leg of the planned and reactive cuts. This was likely due to the tape supporting the line of action of the PL, which may reduce the kinetic demand placed on this muscle, and potentially contribute to a resistance to fatigue. Nonetheless, there was generally minimal effect to the activity of the muscles about the ankle (TA, outside leg PL, PB, SOL) when the joint was taped. These results suggest that the modified subtalar sling is an appropriate preventative ankle taping option for healthy basketball players, as it could restrict joint motion without affecting agility or the typical function of the ankle-foot complex dynamic stabilizing muscles.

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Key points

- Ankle taping using the modified subtalar sling will not affect planned change-of-direction or reactive agility performance as measured by the Y-shaped agility test in healthy male basketball players.
- Ankle taping using the modified subtalar sling will also generally not affect the activity of the muscles about the ankle. There was some indication for reductions in the activity of the PL in the inside leg of certain cuts.
- The tape used for the modified subtalar sling may have supported the line of action of the PL, which could reduce the kinetic demand placed on this muscle, and provide a potential fatigue-reducing component for cutting actions.
- The subtalar sling taping of the ankle in healthy basketball players did not have any adverse effects on the muscle activity of the ankle-foot complex during planned change-of-direction or reactive agility performance tasks.

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