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Original Research

The influence of Mulligan ankle taping during balance performance in subjects with unilateral chronic ankle instability

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ABSTRACT

Objective: : To determine whether Mulligan ankle tape influenced the performance in subjects with unilateral chronic ankle instability (CAI) during static balance; postural sway recovery patterns after hopping and dynamic tracking balance tasks.
Design: : A cross-sectional, within-subjects experimental study design between 4 ankle conditions (taped; untaped: injured and uninjured).
Participants: : 20 volunteer recreational athletes with unilateral CAI were recruited. Means and standard deviations highlighted the athletes' characteristics: age $= 23 \pm 1$ years; height $= 173.1 \pm 2.4$ cm; weight $= 69.3 \pm 3$ kg; Functional Ankle Disability Index (FADI) $= 93.5 \pm 5.1\%$ and FADI Sport $= 84.2 \pm 9.4\%$.
Interventions: : Mulligan ankle taping.
Main Outcome Measurements: : Static balance (10 s); postural sway recovery patterns after a 30 s functional hop test (immediately, 30 and 60 s); dynamic tracking balance tasks (wandering, target overshoot and reaction-time).
Results: : Between the four conditions, static balance showed no significant differences ($p = 0.792$); significant changes occurred in postural sway over time ($p < 0.001$); no significant changes were reported for the dynamic tracking tasks. Wandering was highly correlated with reaction-time and overshooting ($p < 0.01$).
Conclusion: : Under resting and fatigued conditions, Mulligan ankle taping did not impact on the neuromuscular control during static and dynamic balance in subjects with healthy and unstable ankles.

1. Introduction

The ankle joint has been identified as the most frequently injured anatomical site in athletes (Cordova, Armstrong, Ranking, & Yeasting, 1998). The lateral ligament complex is involved in 38–45% of all ankle injuries and is responsible for 1/6 of all time lost from sport (Liu & Jason, 1994). The incidence of chronic instability after ankle sprains is considered to be high (Denegar & Miller, 2002) and a history of at least one ankle sprain is a major predisposing factor (Garrick & Requa, 1973). Three substantial reviews have found that there was no consensus in the literature as to the effective management of athletes who suffer from these chronic ankle instability (CAI) injuries. (Handoll et al., 2001; Thacker, Stroup, & Branche, 1999; Verhagen, van Mechelen, & de Vente, 2000). Furthermore, Hughes & Rochester's review (2008) reports that there is inconclusive evidence to determine the clinical efficacy of the effects of proprioceptive exercise and taping in subjects with chronic ankle injuries.

Contradicting evidence exists regarding changes in postural stability deficits in single leg stance following lateral ankle sprains. Some studies report an increased sway (Guskiewicz & Perrin, 1996; Leanderson, Eriksson, Nilsson, & Wykman, 1996; Tropp, Odenrick, & Gillquist, 1985) while others found no change (Bernier, Perrin, & Rijke, 1997; Ross & Guskiewicz, 2004; Tropp, Ekstrand, & Gillquist, 1984). Research on balance performance after induced-fatigue is limited but there is evidence of increased postural sway in healthy subjects (measured with COP) after induced muscle fatigue at the ankle (Johnston, Howard, Cawley, & Losse, 1998; Vuillerme, Forestier, & Nougier, 2002; Yaggie & McGregor, 2002). Single leg balance protocols have been used as part of chronic ankle rehabilitation. McGuine, Greene, Best, and Leverson (2000) found that the single leg stance test is reliable and valid for predicting ankle injury when using force plates to quantify postural sway.

Nevertheless, the relationship between postural sway and ankle taping during static and dynamic balance activities is still unknown. To treat pain, limitation of ankle movement and altered

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proprioception following an ankle sprain, Mulligan has developed mobilization with movement (MWM). This involves a sustained posterior glide with cephalad inclination to the distal fibula while the patient actively inverts the ankle to the end of pain-free range with over pressure (Vicenzino, Paungmali, & Teys, 2007). To reinforce this treatment technique, two diagonal strips of non- stretch sport tape are applied with a postero-lateral-superior glide of the fibula at the level of the inferior tibiofibular joint (Mulligan, 2003) which differs from the commonly used enclosed ankle taping technique. (Refshauge, Kilbreath, & Raymond, 2000; Wilkerson, 2002).

If Mulligan ankle taping technique proves effective for athletes with CAI, then it could potentially change injury management protocols in clinical practice. It would improve the cost benefit as compared to traditional taping and bracing (Olmsted et al., 2004); facilitate delivery efficiency; reduce physiotherapist time and minimize time lost by athletes in training and competition. To date it appears that no study has investigated the possibility of using the Mulligan ankle taping technique on athletes who suffer from chronic lateral ankle problems during different types of balance tasks. Consequently, the purpose of this study is to examine the effect of ankle taping under resting and fatigued conditions, for improving static and dynamic balance in subjects with healthy and unstable ankles.

2. Methods

2.1. Study design

A within-subjects experimental design was used to compare balance ability between the previously injured leg with residual instability, under taped and untaped conditions, and the uninjured leg under the same taped and untaped conditions.

2.2. Subjects

Twenty otherwise healthy subjects volunteered for the study (8 men, 12 women; mean age 23.0 ± 1.0SD yrs, height 173.1 ± 2.4 cm, weight 69.3 ± 3.0 kg), with a unilateral chronic ankle instability problem. For this study, chronic ankle instability (CAI) was defined as repetitive incidents of ankle sprains due to lateral ankle instability (Hertel, 2002) which may be the result of neural (proprioception, reflexes, muscular reaction time), muscular (strength, power) and mechanical mechanisms (ligamentous laxity) (Konradsen, Olesen, & Hansen, 1998).

For the inclusion criteria, subjects were screened using two questionnaires which were adapted from the Functional Ankle Disability Index (FADI) and Functional Ankle Disability Index Sport (FADI Sport) (Hale & Hertel, 2005; Hubbard & Kaminski, 2002). Subjects were included if they had one uninjured ankle and one ankle which was classified as a CAI injury. Furthermore, subjects were excluded if they had bilateral ankle injuries; an ankle injury within the last 3 months, or any neurological deficit or other injury to the leg that may interfere with proprioceptive acuity and an allergic reaction to rigid sports tape.

Curtin University of Technology Human Research Ethics Committee granted approval and all subjects gave informed consent.

2.3. Testing protocols

At the commencement of the testing, a flip of a coin was used to randomly assign the leg to be taped initially and a further flip of a coin determined which leg would be tested first. To minimize bias, the examiners were blinded to the status of ankle tested (injured; uninjured). However, the order of testing was not randomized due the constraint of the computer software.

Fig. 1 outlines the 3 different testing protocols.

2.4. Measurement screening tools

The FADI (assessment of daily living activities) was scored as a percentage of 104 points and the FADI Sport (assessment of sport-related tasks) was scored as a percentage 32-point scale (Hale & Hertel, 2005). The scores range from 4 (no difficulty at all) to 0 (unable to do) for each activity listed. Hale and Hertel (2005) reported that both FADI and FADI sport were reliable and sensitive for subjects with CAI (ICC 0.89 and 0.84, respectively. Furthermore, Eechaute et al. (2007) confirmed that FADI was the most appropriate instrument for measuring ankle instability.

2.4.1. Taping

Subjects were requested to shave their ankles 24 h prior to the day of testing. The area to be taped was cleaned by alcohol swab

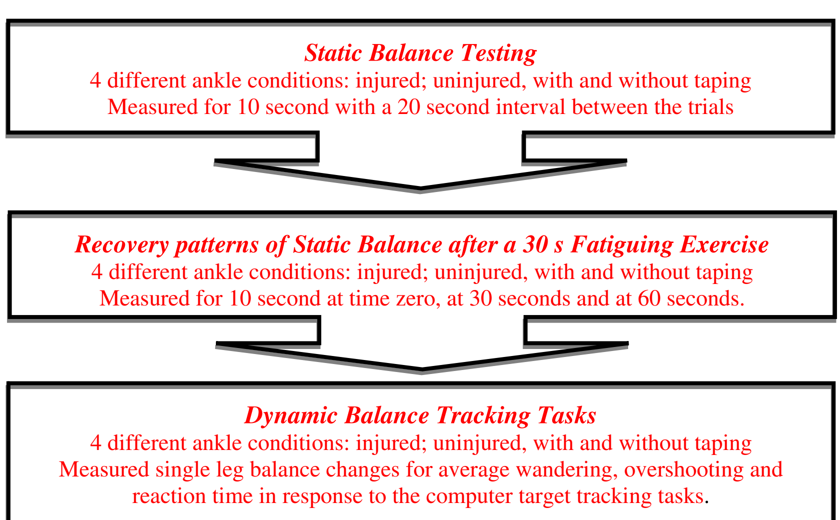

Fig. 1. Flow chart of testing procedure.

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and prepared with Sigma Friar's Balsam (Sigma Pharmaceuticals Ltd, 96 Merindale Drive, South Croydon, New South Wales 3136). The same physiotherapist experienced in the Mulligan ankle taping method (Mulligan, 2003) applied Elastoplast Premium Sports tape (number. 47806, 38 mm) to all the subjects. This Mulligan technique is described in Fig. 2.

2.4.2. Portable force platform calibration

For each of the balancing tasks, the subjects were measured standing barefoot on a portable, stable force platform of 0.5 m × 0.5 m (Accusway Plus, Advanced Mechanical Technology Inc, Watertown, MA). Subjects stood in a relaxed upright position on the force platform with the medial borders of the feet spaced 5 cm apart at the heels. To establish the base of support (BOS) perimeter, 2 anterior points (the tip of the hallux and the head of the 5th metatarsal) and 2 posterior points (medial and lateral aspect of the heel) were calibrated on the force platform using, "AMTI Balance Trainer Program" the computer software program (Rodrigues et al., 2005).

2.4.3. Static balance test

For static balance, a standardized single leg stance position was assumed with the subject's barefoot placed on the previously calibrated position on the force plate. The contra-lateral leg was flexed slightly at the hip with the knee flexed to 90 degrees. Arms crossed the chest with hands resting on the opposite shoulder. The subject was asked to maintain fixed gaze on a cross marked on the wall 3 m in front of them and remain as still as possible for 10s. Force platform CoP data was acquired at 100 Hz. Subjects were tested for understanding of the task requirements prior to formal testing.

2.4.4. Recovery patterns of static balance after a 30 s fatiguing exercise

To standardize the 30 s fatiguing hopping exercise, a stopwatch (6 Digit LCD stopwatch, Digitor) and an electronic metronome was set to establish one hop per second. During the pilot study, it was found that 30 s of hopping was the optimal time before the hopping performance of healthy uninjured subjects deteriorated. Once the 30 s fatiguing hopping exercise was completed, static balance was measured on the force plate at time zero, time 30 s and time 60 s.

2.4.5. Dynamic tracking test

To assess dynamic balance, the subject assumed the single leg balance position and stood on the previously calibrated foot imprint on the force platform. The subjects focussed on the laptop computer screen where circular targets were programmed to appear one at a time in random order at eight positions (0, 45, 90, 135, 180, 225, 27 or 315 degrees). The subjects were asked to respond and move their centre of pressure (CoP) to match the target and hold that position for one second. The targets were ranged within 40% of the distance from the centre and the perimeter of the base of support. This computer software measured three dynamic variables which were defined as: average wandering (defined as the sum of wandering divided by the number of targets), where wandering refers to the accumulated length of the CoP trajectory from the central point to the target; average overshoot (defined as the sum of overshoot divided by the number of targets); where overshoot refers to the maximum straight line distance of the CoP movement outside the perimeter of the target during the 1s hold period; and average reaction time (defined as the sum of target reaction times divided by the number of targets – where reaction time is the time taken for the CoP to exit the origin target perimeter, upon appearance of a new target) (Rodrigues et al., 2005).

2.5. Statistical analyses

To examine changes between the four conditions (injured/uninjured ankle; taped/untaped), a 2 × 2 repeated measures ANOVA (analysis of variance) was completed for the static balance test.

Recovery patterns of Static Balance after a 30 s Functional Hopping Task was assessed using a 2 × 2 × 3 repeated measures ANOVA in which postural sway changes within and between the conditions for 0, 30, and 60 s intervals after the hopping task were evaluated. Pairwise comparisons were computed to detect where the differences occurred.

A 2 × 2 × 3 repeated measures ANOVA was used to examine the differences between the conditions and three variables (wandering, overshoot and reaction time) for the dynamic tracking test. Pearson's correlation tests were performed to determine relationships between wandering, overshoot and reaction times within the same condition.

The significance level for all analysis were set a priori at $p < 0.05$. SPSS program version 13.0 was used to calculate statistics in this study.

3. Results

The results of the two questionnaires showed that FADI 93.46 (5.12) percent and FADI Sport 84.18 (9.44) percent) were higher percentage values than expected for subjects who presented with CAI.

There was no significant difference between the 4 trials in the static balance test in any condition (injured taped F = 0.494, df (1,3) $p = 0.688$; injured untaped F = 0.486, df (1,3) $p = 0.693$; uninjured

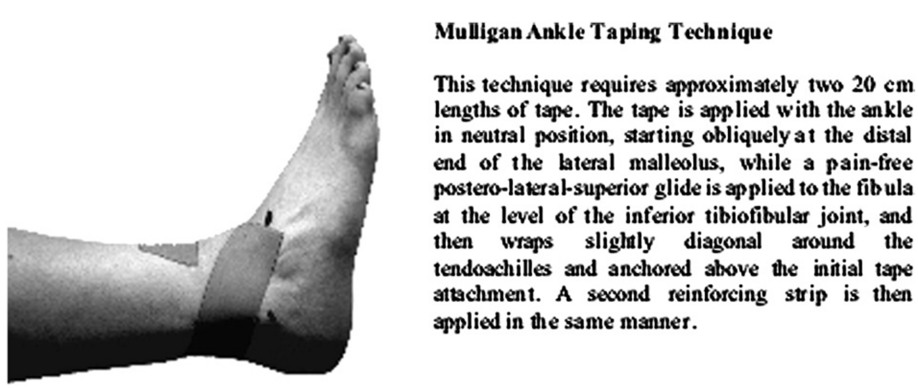

Fig. 2. Mulligan ankle taping.

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Table 1
Means and standard deviations of the best static balance test for the four different conditions (cm^2).

	Uninjured		Injured	
	Untaped	Taped	Untaped	Taped
Mean	2.94	3.12	3.31	3.23
SD	± 0.95	± 1.49	± 1.26	± 1.06

No significant difference $p = 0.792$.

taped F = 0.68, df (1,3) $p = 0.568$; uninjured untaped F = 1.825 df (1,3) $p = 0.153$). This indicated that there was no learning effect between the trials for the four conditions.

Static balance was comparable between the injured and the uninjured ankle joints and Mulligan taping had no affect on static balance performance. (Table 1) During the static balance test, there was no significant interaction between the four conditions (F = 0.071, df (1,19) $p = 0.792$).

Improvement in postural sway during recovery from the 30 s fatiguing task was similar in injured and uninjured ankle joints regardless of Mulligan taping (F = 1.961, df (2,38) $p = 0.155$). However there was a significant change of postural sway over time in all four conditions (F = 9.536, df (2,38) $p < 0.001$). Further pairwise comparisons showed significant differences from 0 to 30 s ($p = 0.049$) and 30–60 s ($p = 0.017$), with an even stronger significant difference demonstrated from 0 to 60 s ($p < 0.001$) Table 2.

The dependent variables have similar mean values between the conditions when analysed individually, therefore demonstrating no significant difference between conditions (wandering F = 0.354, df (1,19) $p = 0.559$; overshoot F = 0.376, df(1,19) $p = 0.547$; reaction time F = 2.353, df(1,19) $p = 0.142$) (Table 3).

Table 4 reported the correlations between wandering, overshooting and reaction time, which were highly significant ($p < 0.01$). An increase in wandering and an increase in overshooting were positively correlated. However two negative correlations existed between an increase in wandering and a decrease in reaction time; and an increase in reaction time and a decrease in overshooting.

4. Discussion

Our study concluded that Mulligan ankle taping does not alter performance in either static or dynamic balancing tasks in relation to chronic ankle injuries. Previous research found that there was no change in function regardless of the taping technique used (Greene & Hillman, 1990; Hume & Gerrard, 1998). However, only one study has specifically investigated the effect of Mulligan ankle taping and reported that this technique prevented recurrent lateral ankle sprains (Moiler, Hall, & Robinson, 2006). These researchers suggested that Mulligan ankle taping could be used with confidence as a preventive method for recurrent ankle injuries.

Static balance was measured by analyzing the area of sway for a period of 10 s. Our findings of no difference between ankles during static balance tests in subjects with unilateral CAI, supports previous studies which investigated static balancing tasks using CoP in injured populations (Bernier & Perrin, 1998; Bernier et al., 1997; Ross & Guskiewicz, 2004; Tropp et al., 1984; Tropp et al., 1985). Possible explanations for these findings have been suggested by Hale and Hertel (2005) who found no difference in area of sway between injured and uninjured ankles in subjects with unilateral CAI. However, when compared to healthy subjects they found an overall significant difference with a larger mean sway area (CoP) in the injured group. Other studies have reported that there is a correlation between greater area of CoP and susceptibility to injury (Gauffin, Tropp, & Odenrick, 1988; Lundin, Feuerbach, & Grabiner, 1993; McGuine et al., 2000) and there is a likelihood that subjects with CAI sustained the injury because of a lack of proprioception due to central mechanisms. This would explain our findings of no significant difference between the ankles in subjects with unilateral CAI.

Another explanation for our findings could be the use of different strategies of balance in subjects with CAI. Tropp et al. (1985) suggested that their subjects compensated by using more proximal strategies (hip) than ankle strategies during static balance which is supported by Pintsaar, Brynhildsen, and Tropp (1996). In our study subjects were instructed to initiate movements from the ankle to avoid hip strategies, however, compensatory balance patterns were observed, but not systematically quantified.

After the 30 s fatiguing exercise, subjects post recovery patterns showed that postural sway area increased immediately in all conditions with the injured untaped condition presenting the largest postural sway mean. No significant change was found between the four conditions however there was a significant difference over time between 0 and 60 s. Since the increase of postural sway has been considered a risk factor for injury (Gauffin et al., 1988; Lundin et al., 1993) the risk appears to be highest immediately after the cessation of the fatiguing exercise. Whereas, recovery of postural sway patterns were spontaneously reduced after 30 and 60 s. Our findings suggested that a 30 s fatiguing exercise was sufficient time to challenge the neuromuscular system and to witness deterioration in postural sway. Regardless of the subject's ankle injury status, Mulligan taping did not impact or alter the recovery time. However, it was difficult to compare our findings with the result of other studies due to differences in research methodology and the undefined taping techniques used. However, induced-fatigue at the hip and ankle has previously been found to increase postural sway area (Gribble & Hertel, 2004; Yaggie & McGregor, 2002) which supports our hypothesis.

Several studies propose the use of dynamic tests to evaluate subjects with ankle sprains (Hrysomallis McLaughlin, & Goodman,

Table 2
Means and standard deviations of the static balance recovery patterns after a 30s hopping task for the four different conditions (cm^2).

Time	Uninjured		Injured	
	Untaped	Taped	Untaped	Taped
0 s	6.71 ± 4.56	6.58 ± 3.27	7.47 ± 3.91	6.67 ± 3.96
30 s	5.59 ± 2.75	6.67 ± 4.60	6.29 ± 3.66	4.63 ± 1.92
60 s	4.48 ± 1.88	4.31 ± 1.72	5.44 ± 3.67	5.71 ± 3.59

Change of postural sway over time in all four conditions were significant ($p < 0.001$).

Table 3
Means, standard deviations and *P* values of the dynamic tracking test variables for the four different conditions.

Dynamic test variables	Uninjured		Injured		*P* Value
	Untaped	Taped	Untaped	Taped	
Wandering (cm)	7.63 ± 2.72	7.08 ± 2.56	8.05 ± 3.38	7.61 ± 2.48	0.559
Overshoot (cm)	0.56 ± 0.16	0.49 ± 0.20	0.58 ± 0.24	0.56 ± 0.19	0.547
Reaction time (s)	0.51 ± 0.16	0.60 ± 0.14	0.56 ± 0.15	0.55 ± 0.13	0.142

Table 4
Correlation (r) values between dynamic tracking test variables for the four conditions.

Dynamic variables	Uninjured		Injured	
	Untaped	Taped	Untaped	Taped
Wandering – overshoot	0.905	0.782	0.909	0.842
Wandering – reaction time	−0.828	−0.814	−0.867	−0.807
Reaction time – overshoot	−0.818	−0.718	−0.763	−0.725

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2006; Wikstrom, Tillman, & Borsa, 2005). In our study, we measured dynamic balance using a novel tracking program. The subjects performed a 30–60 s single leg balancing task with voluntarily displaced center of pressure to hit targets randomly appearing on the computer screen. It was of interest that CAI did not alter the ability to maintain balance with voluntarily induced perturbations during the balancing tasks. Mulligan ankle taping showed no effect on postural sway regarding balancing tasks. A negative correlation between wandering and reaction time and a positive correlation between wandering and overshoot was revealed in this study. As the reaction time increased, the subjects lost accuracy, resulting in a decreased ability to stop, therefore overshooting the target. Functionally, it is suggested that in a sporting situation involving high speed, the ability to control body weight within base of support is decreased. The relationship of wandering and reaction time supports that rapid sudden movement commands for whole body movement about the ankle might reduce voluntary control of the centre of mass.

Our subjects scored an average of 84.8% in the FADI Sport for the injured ankle which could suggest that the functional limitation was low. This could explain findings of no significant differences between injured and uninjured ankles during the static, 30 s fatiguing exercise, and dynamic tracking balance tasks. We suggest that further studies should include the effect of Mulligan ankle taping on subjects with greater functional limitation as well as including a healthy control group instead of using the uninjured contra-lateral ankle for comparison. Furthermore, a recent study (Hubbard, Hertel, & Sherbondy, 2006) reported that the fibula was positioned significantly more anterior in relation to the tibia in subjects with unilateral CAI. For future studies, it would be worthwhile to investigate whether Mulligan taping is effective for these subjects with unilateral CAI.

5. Conclusion

Our study found that Mulligan ankle taping under resting and fatigued conditions, did not impact on the either the mechanical or neuromuscular control during static and dynamic balance in subjects with healthy and unstable ankles.

Conflict of interest

There is no conflict of interest intellectually or financially.

Ethical approval

Curtin University of Technology Human Research and Ethics Committee approved this study and all subjects signed the consent forms.

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