Effects of Kinesio® Taping on Dynamic Balance Following Fatigue: a Randomized Controlled Trial

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ABSTRACT. The objective of the study was to determine the effects of Kinesio taping (KT) in inhibiting fatigue and preserving dynamic balance. Male recreational athletes were recruited to participate in this study. Participants were blinded from the group assignment and divided into four groups (Group A; KT and fatigue, Group B; no tape and fatigue, Group C; KT and no fatigue and Group D; no tape and no fatigue) using sequentially opaque, sealed envelopes. Pre and post measurements of Modified Star Excursion Balance Test (SEBT) composite score and normalized reach distance were used to measure dynamic balance. Adapted Functional Agility Short Term Fatigue Protocol (FAST-FP) was used to induce fatigue. KT was applied to rectus femoris, biceps femoris and medial gastrocnemius of the dominant leg. There was a significant change in the SEBT composite score between groups over time (p<0.05) and in time effect (p<0.05). The main effect comparing the SEBT composite score between the group was not significant (p=0.16). Group A (90.10±9.40) and Group B (86.14±10.50) attained lower mean for SEBT composite score compared to Group C (97.30±10.83) and Group D (98.13±9.47) suggests that fatigue have a diminishing effect on dynamic balance. KT application inhibit the effects of fatigue and preserved lateral and posterior direction of SEBT. KT application may lower the risk for injuries in the lateral and posterior directions following fatigue induction.

Key words: dynamic balance, fatigue, Kinesio Taping, Star Excursion Balance Test (SEBT)

A large volume of literature has reported the high prevalence of sport-related injuries worldwide. The most common injury site is the lower limb, and 23%-67% accounted for the knee. Fatigue has been found to increase the risk of injury. Fatigue is defined as decreased ability of the muscle to contract and exert a force that develops gradually soon after the onset of the sustained physical activity. One of the consequences of fatigue is that it reduces the skill-related physical fitness component such as balance and agility and strength which consequently impaired sports performance.

Dynamic balance has been well established as a vital component of fitness among athletes such as gymnasts, footballer, golfer, ice-hockey players, rifle shooter and taekwondo practitioners. It has been shown that possessing good dynamic balance not only reduces the risk of injuries but would increase sports performance. Unfortunately, these advantages may be limited after fatigue.

Dynamic balance is defined as the ability to maintain the stability of the center of mass during movement. Biomechanical deviations of the lower extremity occur during movement of the center of mass away from the base of support. Balance is gained by maintaining equilibrium in a gravitational field and the ability to react quickly yet efficiently manners toward destabilizing forces to regain stability via postural adjustments. Notwithstanding, these abilities are compromised during fatigue. However, the mechanism of how fatigue affects balance is not fully understood. Cetin et al. (2008) proposed that the afferent feedback system may be interrupted, and conscious joint awareness is altered. Another study also suggested that fatigue seems to have an effect on active joint reposition sense. As a result from muscle fatigue, muscle spindle information became
Consequently, it is plausible to propose a measure to overcome degrading balance following fatigue. One of the relatively new modalities proposed in this study was Kinesio Taping (KT). KT was invented in Japan, in the 1970s by Dr. Kenso Kase. Over the past years, numerous studies have attempted to explain the therapeutic effect of KT on muscle strength, balance, proprioception, range of motion (ROM), pain, movement kinematics, blood circulation, delayed onset muscle soreness (DOMS) and flexibility. However, various literature has provided contradictory findings of the benefits of KT. Moreover, the possible benefits of KT application on dynamic balance in regards to fatigue were also understudied.

Therefore, this study aims to determine the effects of KT in inhibiting fatigue on dynamic balance. The significances of this study are to lead to a deeper understanding of sports injuries in relation to dynamic balance as a result of fatigue. We hypothesized that KT application may inhibit fatigue and preserve dynamic balance.

**Methodology**

This study used a single-blinded, randomized-controlled trial design with pretest and posttest measurements. Participants were randomly assigned to either one of the following groups: Group A (tape was applied and participants were exposed to fatigue), Group B (no tape was applied and participants were exposed to fatigue), Group C (tape was applied and participants were not exposed to fatigue) and Group D (no tape was applied and participants were not exposed to fatigue). The study protocol was approved by the university research ethics committee and also registered with the Australian New Zealand Clinical Trials Registry (ACTRN12614001204639). The statistical power was set at 90% while effect size at 0.25 and p<0.05.

**Subjects**

The investigator randomly assigned the participants using sequentially numbered, opaque, sealed envelopes. Each envelope contains a carbon paper and paper with one of four group code label. No differences in size or weight can be detected between envelopes. Participants’ information was written on the envelopes prior to the opening of the envelope. An audit trail was served with transferring the information to the assignment paper by the carbon paper.

The participants of this study were made up of male recreational athletes ranging from 18-25 years old. Recreational athlete in this study was defined as people undertaking any sports for leisure and not representing the college, national nor international. The participants were instructed to avoid all physical activity 24 hours prior to assessment and to wear sports attire. In order to ensure the reliability of the results, participants that have been diagnosed with musculoskeletal, vestibular and neurological disorder affecting the lower limbs, history of developing pain in the lower limbs due to motor vehicle accident, sports injury and assault to the lower limb and on medication were excluded. The data were collected in a quiet, fully air-conditioned and free of external interference laboratory of the university’s Physiotherapy Department. All participants signed the consent form before any data collection.

**Procedure**

Firstly, all participants who met the eligibility criteria of the study and consented to participate were provided an explanation and written summary of the experimental procedure. Secondly, participants’ demographic data were taken, including age, body weight, height, and body mass index. Next, the investigator would open the coded sealed opaque envelope. To ensure blinding, the participant was blinded from the group assignment. Next, participants in Group B or Group D directly proceed to the familiarization and warming-up session. While for participants in Group A or Group C, the participants were applied with KT before proceeding to the familiarization and warming-up session. The participants warmed up for 5 minutes by jogging on a treadmill at a preferred speed, then carried out lower limb muscle stretching with 15 seconds hold. Assessment procedures were explained, and participants then performed four practice trials of Star Excursion Balance Test (SEBT). Prior to the testing session, participants’ maximum vertical jump was recorded. Participants then performed the SEBT. Next, fatigue was induced to participants in Group A and Group B by performing the fatigue induction protocol. After the completion of the fatigue induction, the measurements similar to the pretests were repeated. For Group C and Group D, fatigue induction protocol was replaced by a rest period of 2-3 minutes before proceeding to posttest measurements.

**Dynamic Balance**

The dynamic balance was assessed by the Star Excursion Balance Test (SEBT). Measurements for each direction were carried out three times before and after fatigue with the best performance were recorded as the participants’ score. The starting position was randomized to eliminate learning effect. The maximum reached distance was measured in centimeters (cm). The reached distance values were used as an index of dynamic postural-control. In the other words, the higher the distance being reached reflects, the better dynamic postural-control.

The original SEBT consisted of eight directions, and it was first described by Gray in 1995. The original eight directions have been shown to have intraclass reliability ranging from 0.78 to 0.96 while the interclass reliability of 0.35 to 0.93. For the purpose of this study, the modified SEBT consisting of four directions including anterior, mediolateral,
eral and posterior were used\(^{(2)}\). More recent study has proposed that a modified four directions SEBT is more practical and may achieve the same validity as the original test due to reduction of measurement time up to 85\% and placed lesser physical burden to participants\(^{(2)}\). This practicality may be very relevant to this study as it will minimize the recovery effect from fatigue.

In setting up the modified SEBT, four scale markers were placed at an angle of 90° to each other. Participants placed the tested or dominant leg in the center of the grid. The directions of the test depended on the dominant leg. The test was performed counterclockwise if the dominant leg is right and clockwise if the dominant leg is left. Participant reached the non-dominant leg as far as possible in each of the four directions, touched lightly on the line, and returned to a double leg stance in the center.

**Kinesio Taping (KT) Application**

KT was applied to the rectus femoris of the quadriceps, biceps femoris of the hamstring, and medial gastrocnemius of the dominant leg because of the susceptibility of these muscles to injuries. The dominant leg was defined as the preferred kicking leg. The “Y” technique was used to attain the muscle facilitation stimulus effects. The tape was applied using the technique proposed by Kase et al. (2003) and the tape was fixed from the origin to the insertion direction. No tension was provided in the base application while moderate tension (50-75\% of the available tape length) was given along the tape. The tape was always applied 30 minutes before warming-up by the same certified person. Once the tape was applied, the tape was used throughout the study (approximately two hours). The applied tape was regularly checked. When the edge of the tape began to lift, it was trimmed. When the tape came off during the procedure, a new tape was applied and the participants were asked to restart the experiment procedure from the beginning.

For KT application to the rectus femoris muscle, the participants were positioned in standing with the dominant leg fully bent. Both of “Y” tail tape was applied to the anterior inferior iliac spine to surround the muscle. The tail ended at the tibial tuberosity. For KT application to the biceps femoris muscle, the participants were positioned in standing and both hands reaching the toes. The base was started two centimeters below the ischial tuberosity and end at the medial head of the fibula. For KT application to the medial gastrocnemius muscle, the participants were positioned in lunges with the non-dominant leg. The knee of the dominant leg kept straight with ankle fixed on the floor. For the base application, one of the “Y” tails of the tapes was applied two centimeters below the medial condyle of the femur where the medial head of gastrocnemius originated. The distal end was applied to the insertion of the gastrocnemius at the calcaneus.

**Exposure to fatigue**

An adapted Functional Agility Short Term Fatigue Protocol (FAST-FP) was used to induce fatigue for Group A and B. This protocol consisted of vertical jumping, stepping up and down, squatting and L-Drill\(^{(35-37)}\). Prior to starting, participants’ maximum vertical jump was recorded. On embarking in the fatigue protocol, participants first performed three consecutive vertical jumps. Next, participants performed a series of step up and down a 30 cm box for 20 seconds at 220 beats per minute (bpm). Afterward, participants performed three consecutive squatting to 90° knee flexion. Finally, participants performed L-Drill. L-Drill consisted of three cones that were set in the shape of an L with 4.05 meter apart. Participants started at starting cone, sprinted to the first cone and sprinted back to the starting cone. Then participants sprinted to the first cone, ran around it and cut inside to the second cone. Participants ran in a circle around the second cone from the inside to the outside and sprinted around the first cone before running to the starting cone. Completing the four tasks (vertical jumps, step-up and down, squatting and L-Drill) were counted as one set of the protocol. This was repeated until maximal fatigue is achieved. Fatigue criteria are manifested by the participants achieving less than 90\% of the maximal jump on all three vertical jumps for two consecutive fatigue sets\(^{(37)}\). From the manifestation of fatigue to the data collection, the time frame was less than 10-15 seconds. The purpose of following this time frame is to minimize muscular fatigue recovery. Exceeding this may improve performance\(^{(7)}\).

**Data Analysis**

Data were analyzed using SPSS version 20 (SPSS Inc., Chicago, IL, USA). The level of significant differences was set at \(p<0.05\). Descriptive statistics were performed on demographic data including age, height, and body weight and body mass index and were reported as means (m) and standard deviations (SD). A one-way analysis of the variance was used to determine the baseline demographic differences between the groups. All variables were tested for normality of distribution. Mixed between-within subjects analysis of the variance and Bonferroni test were used to compare the means of the groups to determine whether a significant difference existed between the groups. Main effects were classified into time and group. Main effect of time is the significant difference between the means in pre and post while the main effect of group is the significant difference between the mean across four groups. Interaction effect is the interaction of the main effect of time and group or the significant difference between the means in pre and post across four groups.

Reach distance was normalized to limb length to allow comparison between participants. To calculate reach distance as a percentage of limb length, reach distance was divided by limb length then multiplied by 100. To calculate
between groups were observed (p=0.19). Similarly, no significant difference in mean (SD) body weight between groups were observed (p=0.19). The mean (SD) body weight for Group A was 66.37 (1.58) kg, Group B was 62.58 (2.16) kg, Group C was 65.26 (1.56) kg and Group D was 63.63 (3.24) kg. Next, the mean (SD) height for Group A was 1.71 (0.05) meter, Group B was 1.67 (0.06) meter, Group C was 1.70 (0.06) meter and Group D was 1.68 (0.04) meter. No significant difference in mean (SD) height between groups were found (p=0.23). The baseline characteristics of study participants were illustrated in Table 1. Significant changes were found in the SEBT composite scores over time among the four groups, (p<0.0005, ηp²=0.51). Time had a substantial effect (p<0.0005, ηp²=0.45), demonstrating that there were changes in the SEBT composite score in pre and post measurements. The main effect based on the SEBT composite scores among groups was not significant (p=0.16, ηp²=0.07), demonstrating that the changes in the SEBT composite score between the four groups were not significant. The results is illustrated in Table 2.

Table 3 shows the means of the normalized reach distance between four groups across two-time periods.

For the anterior direction, group effects indicated that there were no significant changes between all groups (p=0.35). Time effects indicated that the normalized reach distance significantly changed (p<0.05) after the induction of fatigue. Group A showed a 7.50% (p<0.001) reduction while Group B showed an 11.55% (p<0.001) reduction. This suggests that fatigue reduced the anterior direction normalized reach distance. No significant changes were found in the post reach distance mean for Group C (0.68%, p=0.86) and Group D (−0.53%, p=0.22).

Group effects indicated that there were no significant changes between all groups (p=0.19) for the medial direction. Time effects indicated that the medial direction normalized reach distance significantly changed (p<0.05) after the induction of fatigue. Group A showed a 6.05% (p<0.001) reduction while Group B showed a 13.22% (p<0.001) reduction. This suggests that fatigue reduced the medial direction normalized reach distance. No significant changes were found in the post medial direction normalized reach distance for Group C (0.68%, p=0.58) and Group D (−0.55%, p=0.25).

Time effects indicated that the lateral direction normalized reach distance significantly changed (p<0.05) but non-significant in group effect (p=0.35). Surprisingly, significant reduction of the normalized reach distance mean were seen in the Group B (9.60%, p<0.001) and Group D (−1.36%, p<0.03). No significant changes was found in Group A (4.52%, p=0.29) and Group C (−8.62%, p=0.41).

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### Table 1. Characteristics of the participant (N=72) at baseline.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Group A (n=19)</th>
<th>Group B (n=19)</th>
<th>Group C (n=19)</th>
<th>Group D (n=15)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>21.32 (1.29)</td>
<td>21.79 (1.44)</td>
<td>21.11 (1.33)</td>
<td>21.93 (0.88)</td>
<td>0.19</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>66.37 (1.58)</td>
<td>62.58 (2.16)</td>
<td>65.26 (1.56)</td>
<td>63.63 (3.24)</td>
<td>0.58</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.71 (0.05)</td>
<td>1.67 (0.06)</td>
<td>1.70 (0.06)</td>
<td>1.68 (0.04)</td>
<td>0.23</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>21.16 (1.46)</td>
<td>22.61 (2.86)</td>
<td>21.59 (1.67)</td>
<td>22.26 (2.39)</td>
<td>0.97</td>
</tr>
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</table>

### Table 2. Composite score between Four Groups across Two-Time Periods

<table>
<thead>
<tr>
<th>Composite score (%)</th>
<th>Group A (n=19)</th>
<th>Group B (n=19)</th>
<th>Group C (n=19)</th>
<th>Group D (n=15)</th>
<th>Main Effect</th>
<th>Interaction Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m (SD)</td>
<td>m (SD)</td>
<td>m (SD)</td>
<td>m (SD)</td>
<td>(Time) (Group)</td>
<td>(Time*Group)</td>
</tr>
<tr>
<td>Pre</td>
<td>95.66 (9.10)</td>
<td>97.84 (9.90)</td>
<td>97.68 (10.91)</td>
<td>97.20 (9.00)</td>
<td>&lt;0.0005*</td>
<td>0.16</td>
</tr>
<tr>
<td>Post</td>
<td>90.10 (9.40)</td>
<td>86.14 (10.50)</td>
<td>97.30 (10.83)</td>
<td>98.13 (9.47)</td>
<td>&lt;0.0005*</td>
<td>&lt;0.0005*</td>
</tr>
<tr>
<td>Differences</td>
<td>5.56</td>
<td>11.70</td>
<td>0.38</td>
<td>−0.93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig.</td>
<td>&lt;0.05*</td>
<td>&lt;0.05*</td>
<td>0.70</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table Legends: *Significant at p<0.05
Effects of Kinesio® Taping on Balance

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Normalized Reach Distance between Four Groups across Two-Time Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normalized reach distance (%)</td>
</tr>
<tr>
<td>Anterior</td>
<td>Pre 93.48 (10.59)</td>
</tr>
<tr>
<td></td>
<td>Post 85.98 (14.13)</td>
</tr>
<tr>
<td></td>
<td>Differences 7.50</td>
</tr>
<tr>
<td></td>
<td>Sig. &lt;0.001*</td>
</tr>
<tr>
<td>Medial</td>
<td>Pre 84.39 (12.70)</td>
</tr>
<tr>
<td></td>
<td>Post 78.34 (13.85)</td>
</tr>
<tr>
<td></td>
<td>Differences 6.05</td>
</tr>
<tr>
<td></td>
<td>Sig. &lt;0.001*</td>
</tr>
<tr>
<td>Lateral</td>
<td>Pre 100.48 (10.40)</td>
</tr>
<tr>
<td></td>
<td>Post 95.96 (10.40)</td>
</tr>
<tr>
<td></td>
<td>Differences 4.52</td>
</tr>
<tr>
<td></td>
<td>Sig. 0.29</td>
</tr>
<tr>
<td>Posterior</td>
<td>Pre 104.30 (10.58)</td>
</tr>
<tr>
<td></td>
<td>Post 100.03 (9.75)</td>
</tr>
<tr>
<td></td>
<td>Differences 4.27</td>
</tr>
<tr>
<td></td>
<td>Sig. 0.19</td>
</tr>
</tbody>
</table>

Table Legends: *Significant at p < 0.05

For the posterior direction, time effects indicated that the normalized reach distance significantly changed (p < 0.05). Only Group B showed a significant reduction of the post reach distance mean (12.43%, p < 0.001) while no significant changes in Group A (4.27%, p = 0.29), Group C (–0.01%, p = 1.00) and Group D (0.80%, p = 0.13). Group effects indicated that there were no significant changes between all groups (p = 0.94) for the posterior direction.

No significant differences were found in post normalized reach distance mean for lateral and posterior direction in Group A.

Significant reduction were found in normalized reach distance in Group A for anterior (p < 0.001) and medial (p < 0.001) direction, and in Group B for anterior (p < 0.001), medial (p < 0.001), lateral (p < 0.001), and posterior (p < 0.001) direction. These suggest that KT application inhibit the effects of fatigue and preserved lateral and posterior direction of SEBT. Moreover, the normalized reach distance after fatigue induction in Group A were above the cut-off point of 94% for lateral (95.96±10.40) and posterior (100.03±9.75) directions. This suggest that KT application may lower the risk for injuries in the lateral and posterior directions following fatigue induction.

**Discussion**

The current study aims to determine the effects of KT in inhibiting fatigue and preserve dynamic balance. The findings revealed that fatigue significantly down-regulated dynamic balance. This was indicated by lower normalized reach distance in all directions and SEBT composite score after muscle were induced to fatigue. The results were consistent with that of earlier findings that reported fatigue caused deterioration of dynamic balance. These results may be caused by the reduced function of the muscle as characterized by reduced muscle response to neural excitation and reduced contraction activities of the muscles that caused reduced in force exertion. Compromised force exertion reduced the efficiency to execute optimal dynamic balance. Furthermore, fatigue of the large groups of muscles that control the hip and knee joints altered the kinematic movement pattern, thereby hampering the dynamic balance.

The current study also revealed that KT application significantly inhibits down-regulation of dynamic balance due to fatigue. This can be seen in the preservation of reach distance in lateral and posterior directions. However, reach distance in anterior and medial directions were significantly reduce even with present of KT. The explanations for these findings were certain directions in the SEBT require activation and contribution of certain muscles. According to previous studies, biceps femoris was most active posterior, lateral and posterolateral directions, vastus medialis obliquus in anterior direction, while vastus lateralis in the medial di-
tion did not enhance dynamic balance. Among the possible mechanisms on how KT application preserved dynamic balance by inhibits the effects of fatigue were tactile stimulus and mechanoreceptor stimulation provided by KT compensated for the loss of the afferent feedback caused by the effect of fatigue. This condition may assist in the maintenance of muscle spindle information accuracy, thereby preserving the proprioceptive input flow contributed by the muscle spindles. In this manner, the compensatory mechanism for diminished sensory input flow (i.e., postural sway) may be minimized, thereby retaining the ability to maintain efficiently the stability of the center of mass during movement. In addition, the reach distances in lateral and posterior direction were greater than the cut of point (94%). Therefore it is plausible to suggest that KT application might reduce the risk of fatigue-related sports injury. However, we cannot confirm this. Further investigation is warranted in the matter.

However, past studies have reported that KT application did not enhance dynamic balance. The possible causes of the inconsistency were differences in KT application techniques and muscles being taped. Moreover, the benefits of KT application may not be detected on participants with no balance deficits because the participants in the previous studies were not induced to fatigue. In addition, previous studies were conducted only on a small size, for example, n=15 in Bicici et al. and n=20 in Nunes et al.

This study has several limitations that should be considered. Firstly, only male recreational athletes aged ranging from 18 to 25 years old were included, limiting the generalization of the findings to female athletes, young athletes and athletes at all levels of performance including semi-professional and professional athletes. Next, the fatigue induction only reflects general sports activities and did not replicate specific sports’ physiological demand and the activity pattern.

Future research should include both genders athletes from different levels of performance. Both genders have different physiological properties, and athletes from different levels of performance have different skill proficiencies. In addition, more sports-specific fatigue induction protocol should be used as different sports have different physiological demand and the activity pattern.

The findings of this study may help coaches and athletes to consider the benefit of KT application in inhibiting fatigue. Preservation of the dynamic balance may be advantageous during sports activities and reducing the risk of injuries.

Conclusion

There are a few conclusions can be drawn from the present study. Firstly, fatigue significantly reduces the dynamic balance that may lead to increased risk of sports injury that is revealed by lower normalized reach distance in all direction and SEBT composite score following fatigue. Secondly, KT application inhibits fatigue and preserves dynamic balance.

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Conflict of Interest: Authors have no conflict of interests to disclose.

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