KJSB

Korean Journal of Sport Biomechanics 2018; 28(3): 193-197
http://dx.doi.org/10.5103/KJSB.2018.28.3.193
http://e-kjsb.org eISSN 2093-9752

ORIGINAL

Effect of Different Rest Intervals on Ankle Kinematics during a Dynamic Balance Task

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Received : 12 April 2018
Revised : 27 July 2018
Accepted : 29 July 2018

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Objective: The relationship between the rest intervals during physical tasks and performance enhancement has been studied. However, whether or not different rest intervals would result in altered multiplanar ankle kinematics during performance of the Star Excursion Balance Test (SEBT) is unknown.

Method: Fifteen healthy subjects (7 males and 8 females) without a history of ankle injuries were participated in this study. 3 rest intervals of 10, 20, and 40 seconds were used during the current study. Three visits were required in order to complete the 3 rest intervals. Variables of interest included dorsiflexion (DF) excursion, tibial internal rotation (TIR), and eversion (EV) excursions. The means of ankle angular excursions were compared across the 3 directions in the 3 rest interval groups.

Results: There were no significant main effects for any variables between rest intervals. However, DF excursion in the anteromedial (AM) direction was greater than in both the medial (M) and posteromedial (PM) directions and was greater in the M direction compared to the PM direction. TIR excursion in the AM direction was less than in both the M and PM directions.

Conclusion: Different rest intervals ranging from 10 to 40 seconds did not influence ankle angular excursions during the SEBT in a healthy population. However, our results suggest that multiplanar motion is necessary during the SEBT and differs depending on the direction of movement.

Keywords: Star excursion balance test, Ankle, Kinematics, Postural control

INTRODUCTION

One specific type of ankle sprain dysfunction is chronic ankle instability (CAI) which is characterized by decreased neuromuscular control (Riemann, 2002). A common measure of neuromuscular control and dynamic postural control in this population is the Star Excursion Balance Test (SEBT) (Hertel, Braham, Hale, & Olmsted-Kramer, 2006). The SEBT measures the maximum reach distance of the free leg during a single-leg stance to detect functional deficits related to pathologies such as CAI (Hertel et al., 2006). The SEBT demonstrates high reliability and validity in healthy individuals and consists of 8 directions (Hertel, Miller, & Denegar, 2000). Although subjects with CAI have a diminished reach distance compared with healthy subjects, causative factors related to this diminished reach distance have not been well established (Hertel et al., 2006; Kim & Park, 2016).

Previous studies have primarily focused on sagittal plane motion of the lower extremity as causative factors affecting performances on the SEBT. For example, ankle dorsiflexion, hip flexion, or knee flexion was strongly associated with the performance of the SEBT in the anterior, anterolateral and anteromedial, or medial, posterior, posterolateral, and posteromedial directions (Hoch, Staton, & McKeon, 2011; Robinson & Gribble, 2008). On the contrary to this, frontal and transverse plane at the hip had no effect (Robinson & Gribble, 2008). Performance of the SEBT requires pronation and supination of the ankle while the foot constantly remains on the floor (Hubbard & Hertel, 2006; Richie Jr, 2001). Thus, lower extremity movement at distal joints in multiplanar motion is important to perform the SEBT. However, to our knowledge, no one examined multiplanar motion at the ankle during the SEBT.

Most researchers have used rest intervals of 15 to 20 seconds between trials or have not mentioned an exact rest interval time, although previous studies have largely investigated the effect of rest interval time on performance of various tasks (Abt, Siegler, Akubat, & Castagna, 2011; Dabbs, Munoz, Tran, Brown, & Bottaro, 2011; Gribble, Hertel, & Denegar, 2007; Hertel et al., 2006; Hertel et al., 2000; Hyun & Ryew, 2016; Nogueira et al., 2012; Olmsted, Carcia, Hertel, & Shultz, 2002). For example, rest intervals between whole body vibration and a vertical jump test have been investigated and it is shown that over-stimulation of the neuromuscular system occurs with short rest intervals. On the other hand, benefits of the warm-up may dissipate during rest intervals that are too long (Dabbs et al., 2011).

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Based on previous studies, rest intervals during the SEBT may alter ankle kinematics in multiplanar motion during a balance task. It has been suggested that altered kinematics of the lower extremity as factors may affect performance of the SEBT (Hoch et al., 2011). However, to our knowledge, no study has examined the relationship between rest intervals and ankle kinematics on the SEBT. Therefore, our purpose was to determine if there were differences in multiplanar motion at the ankle during performance of the SEBT across 3 different rest intervals. Our hypothesis was that different rest intervals may result in altered multiplanar motion at the ankle.

METHODS

1. Participants

The participants consisted of 7 males (age: 21.4 ± 1.1 years, height: 173.8 ± 6.5 cm, mass: 71.1 ± 6.8 kg) and 8 females (age: 21.9 ± 1.7 years, height: 161.9 ± 6.8 cm, mass: 52.3 ± 5.9 kg). The participants completed an injury history questionnaire and all participants reported no history of lower extremity injury including ankle sprains. The participants were also free from vestibular disorders and head injury for the previous 6 months. Finally, prior to participation, all participants gave written informed consent approved by the University Institutional Review Board.

2. Procedure

The participants were initially assigned one of the three rest intervals (10, 20, 40 seconds). We selected rest intervals that were 2 times greater and smaller than the previously used rest interval of 20 seconds (Gribble et al., 2007; Hertel et al., 2006; Hertel et al., 2000; Olmsted et al., 2002). Longer than 40 seconds was not selected due to an unrealistic rest interval time used in the clinic. The order of rest intervals and reach directions (anteromedial: AM, medial: M, posteromedial: PM) were randomized and counterbalanced. The participants required a total of 3 visits with a 48-hour period between visits. Participants stood their non-dominant barefoot, an opposite side to preferred kicking foot, in the center of a grid. The grid was formed by 3 directions which were marked with the AM and PM directions at 45 degrees with the direction for M (Kwon & Blaise Williams, 2017). The three directions have been used to discriminate between individuals with and without CAI (Hertel et al., 2006). The participants were instructed to reach their dominant big toes as far as possible along the three directions and lightly touch the floor with no weight shift (Figure 1). When the participants reach each direction, they return the big toes to the grid center while they kept their hands on their waists (Kwon & Blaise Williams, 2017). If they moved their foot from the original foot location, lifted their foot from the ground, released their hands from their waists, or lost their balance, trials were not counted. The participants performed 7 consecutive trials of the SEBT in each of the 3 directions. The first 4 trials were practice and the last 3 trials were recorded (Robinson & Gribble, 2008).

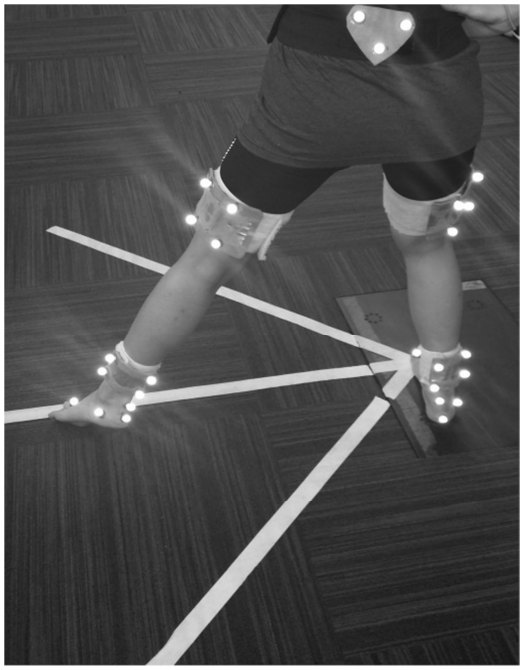

Figure 1. Lower extremity marker placement and completion of SEBT in the medial direction.

3. Data analysis

The three-dimensional motion analysis (VICON MXF20, VICON Motion System, Centennial, CO) with 12 infrared cameras was used to collect ankle kinematic data at 100 Hz. Reflective markers were attached to the non-dominant bases of the 1st and 5th metatarsal, lateral and medial malleoli, distal, proximal, and lateral heel, lateral and medial epicondyles of the femur, and lateral part of the lower leg (Figure 1) (Ferber, McClay Davis, Williams, & Laughton, 2002). Velocity was calculated by detecting movement of the reflective marker on the big toe to determine starting and ending points in each direction. First zero-velocity indicates the starting point and third zero-velocity indicates the ending point. Joint angles of dorsiflexion (DF) (extension of the foot), eversion (EV) (the sole of the foot is turned laterally) and tibial internal rotation (TIR) (tibia is rotated internally) between initial and peak points were measured using Visual 3D data analysis software (C-Motion) to calculate angular joint excursions (maximum angle - minimum angle) (Kwon & Blaise Williams, 2017).

4. Statistical analysis

The means of ankle joint excursions for TIR, DF and EV from the last 3 trials of each direction of the SEBT were used. Two-factor analyses of variance (rest interval X direction) were used to compare all dependent variables across the 3 directions in the 3 rest interval groups. Post-hoc comparisons using Fisher's Least significant Difference were performed to assess specific differences when there was a significant difference among groups (10, 20, 40 seconds) or directions (AM, M, PM). The level of significance was set at 0.05 for all comparisons.

Table 1. Mean (SD) for Dorsiflexion (DF), Eversion (EV), Tibial Internal Rotation (TIR) Excursions

Direction	10s	20s	40s	Mean of reach distance
DF				
AM	13.0 (6.0)	12.7 (5.0)	13.8 (4.5)	13.2 (5.1)*,±
M	11.2 (6.1)	11.8 (5.8)	12.2 (4.8)	11.8 (5.46)¥
PM	9.4 (5.9)	8.9 (6.6)	9.7 (3.6)	9.3 (5.4)
Mean of rest interval group	11.2 (6.1)	11.1 (5.9)	11.9 (4.6)	
EV				
AM	5.8 (2.2)	4.6 (2.6)	4.3 (3.8)	4.9 (2.9)
M	5.1 (2.6)	4.5 (2.0)	4.4 (3.8)	4.7 (2.8)
PM	4.8 (2.7)	4.4 (2.6)	5.3 (3.8)	4.9 (3.0)
Mean of rest interval group	5.2 (2.5)	4.5 (2.3)	4.7 (3.7)	
TIR				
AM	6.9 (3.4)	5.9 (5.5)	6.7 (2.6)	6.5 (3.9)
M	8.9 (3.6)	7.9 (5.1)	8.2 (4.7)	8.3 (4.4)*
PM	9.1 (3.9)	7.9 (5.0)	8.5 (4.0)	8.5 (4.3)±
Mean of rest interval group	8.3 (3.7)	7.2 (5.2)	7.8 (3.9)	

Abbreviation: AM, anteromedial; M, medial; PM, posteromedial
*±¥p < .05, significant difference between directions
*AM vs. M, ±AM vs. PM, ¥M vs. PM

RESULTS

1. Dorsiflexion excursion

For ankle DF angular excursion, there were no significant main effects for rest intervals ($F_{2,126}$ = 0.28, p = 0.76). However, there were significant main effects for reach directions ($F_{2,126}$ = 5.76, p = 0.004). Post hoc tests revealed ankle angular DF excursion in the AM direction to be greater than in both the M direction (p = 0.001) and PM direction (p = 0.001), with the M direction greater than the PM direction (p = 0.001) (Table 1). An interaction within subjects was not detected for the rest interval groups by reach directions ($F_{4,126}$ = 0.05, p = 0.99).

2. Eversion excursion

For ankle EV angular excursion, there were no significant main effects for rest intervals ($F_{2,126}$ = 0.71, p = 0.49) and reach directions ($F_{2,126}$ = 0.11, p = 0.90). Furthermore, an interaction within subjects was not detected for the rest interval group by reach direction ($F_{4,126}$ = 0.60, p = 0.66). Table 1 shows EV excursion values across the 3 directions in the 3 rest interval groups.

3. Tibial internal rotation excursion

For ankle TIR angular excursion, there were no significant main effects for rest intervals ($F_{2,126}$ = 0.70, p = 0.50). However, there were main effects for reach directions ($F_{2,126}$ = 2.99, p = 0.05) among participants. Post hoc tests revealed the angular excursion of TIR in the AM direction to be lesser than in both the M direction (p = 0.001) and PM direction (p = 0.003) (Table 1). A significant interaction within subjects was not detected for the rest interval group by reach direction ($F_{4,126}$ = 0.31, p = 1.0).

DISCUSSION

The purpose of the current study was to investigate ankle kinematics during the SEBT at different rest intervals. Our hypothesis was that kinematic patterns including DF, EV, and TIR excursions on the SEBT would be different between reach directions and between the different rest intervals. There were no differences in kinematic patterns between the 3 rest intervals. However, there were differences in kinematic patterns that existed when comparing reach directions.

Controversy exists as to whether impairments in lower limb range of motion have an effect on SEBT performance. Gribble and Hertel indicated that weight-bearing active DF range of motion in the ankle is not significantly related to the performance of the SEBT (Gribble & Hertel, 2003). In a similar study, Hoch et al. reported that maximum weight-bearing active DF range of motion in the ankle measured during a weight bearing lunge test has a strong correlation with the anterior reach direction, but not posteromedial and posterolateral directions during the SEBT (Hoch et al., 2011). Our results indicate that DF excursion was progressively decreased from AM to PM during the SEBT. Our

findings are consistent with Hoch et al. and indicate that the anterior direction has the greatest DF excursion compared to the posterior direction (Hoch et al., 2011). Therefore, we suggest that DF excursion in the ankle is an important factor influencing SEBT performance. In a similar study, Robinson and Gribble found that flexion of the knee and hip in the sagittal plane accounts for 78.1% of the variance in the anterior direction (Robinson & Gribble, 2008). In addition, Tabrizi et al. have reported that individuals with recurrent ankle sprains or after initial ankle sprain have shown decreased active DF ROM and suggested that decreased DF ROM can be a risk factor resulting in CAI (Tabrizi, McIntyre, Quesnel, & Howard, 2000). Thus, individuals with recurrent ankle sprains may have a decreased maximum anterior reach direction during the SEBT due to decreased DF ROM. If individuals with decreased DF ROM restore their DF ROM through rehabilitation including strengthening dorsiflexors and stretching plantarflexors, they may have an increased maximum anterior reach direction during the SEBT.

Although EV excursion was unchanged across rest intervals and reach directions, examining the EV motion of the ankle is meaningful to understand the movement pattern during the SEBT. Much work has been focused on sagittal plane movement of the ankle, knee, and hip because the SEBT demands more sagittal plane movement than other planes (Gribble & Hertel, 2003; Gribble, Hertel, & Plisky, 2012; Hoch et al., 2011). The ankle can be moved in multiple planes in addition to dorsiflexion and plantarflexion. Although during the SEBT, minimal eversion movement is possible due to the foot fixed on the ground ankle motion is still required in the frontal plane during the SEBT (Gribble et al., 2012). Eversion was chosen as the subject's center of mass moves medially during each of the reach directions. It is possible that participants with instability in the ankle may show differences in ankle eversion during the SEBT.

Excursion of TIR in the AM direction was smaller than both in M and PM directions. There were no differences between TIR excursions in the M and PM directions. TIR is a transverse planar motion of the lower leg and these results indicate that M and PM directions of the SEBT place demands on neuromuscular function that controls the transverse plane in the lower leg (Nawoczenski, Cook, & Saltzman, 1995). While TIR is more pronounced in the proximal joints than EV or DF, TIR does not occur without distal joint motion at the foot. Therefore, it is necessary to examine the coordination of these movements for future study.

CONCLUSION

Varying rest intervals between 10 and 40 seconds did not influence ankle angular excursions during the SEBT in a healthy population. There is a progressively decreased demand for ankle DF when moving from the AM to PM directions. Limitations in DF may result in unwanted transfer of motion up the chain during activities that require anterior reaching. Contrary to our results in DF, TIR of ankle in the AM direction occurs less than in both the M and PM direction. This suggests that multiplanar motion is necessary during a complex functional movement and may play an important role in dynamic postural control. There were a few limitations to this study. Understanding ankle kinematics during the SEBT may lead researchers and clinicians to develop targeted treatment and prevention strategies for CAI. However, our study has only investigated healthy subjects. Therefore, the results of this study cannot measure the difference of ankle kinematics between healthy individuals and those with CAI to develop a targeted treatment for CAI. This study also did not investigate the lower extremity mechanics in the other directions of the SEBT. Future studies will focus on the comparison of healthy subjects and those with CAI across all reach directions.

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