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High Volume Versus Low Volume Balance Training on Postural Sway in Adults with Previous Ankle Inversion Injury

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ABSTRACT

Balance training is commonly used in the rehabilitation process of ankle injuries; however, the exercise prescription guidelines for preventing balance training are poorly understood. The aim of the present study was to determine if high or low volume balance training is more effective in improving postural sway after an 8 week balance training program utilizing the same exercise. Seventeen subjects (14 male, 3 female) with a mean age of 24.08 ± 5.6 years were randomly allocated into a control group (CG), low volume training (LVT) or high volume training (HVT). All subjects had sustained at least two inversion ankle injuries within the last 18 months. Subjects completed 8 weeks of balance training of up to 30 mins duration, 3 times per week. LVT consisted of 40 repetitions for week 1, progressing to 60 repetitions by week 8. HVT consisted of 60 repetitions for week 1, progressing to 120 repetitions by week 8. The maximum centre of pressure (COP) excursion was obtained from the force plate in the medio-lateral (ML) direction and subsequently used for pre-test and post-test analysis. After the 8 week training intervention, there was a significant (P < 0.001) difference in postural sway between pre and post testing for both the LVT (pre: 88.40mm ± 25.06mm, post: 72.17mm ± 27.55mm) and HVT (pre: 77.4 mm ± 10.3 mm, post: 58.34mm ± 7.0mm) groups. There was no significant (P > 0.01) difference detected for improvements between the LVT and HVT, however, reported effect sizes (ES) showed large effect size changes in the high volume training (ES = 1.7) whereas low volume training showed medium effect size changes (ES = 0.6). This preliminary study demonstrates the importance of training volume in the rehabilitation of ankle injuries, with HVT being superior to LVT.

Keywords: Balance, Proprioception, Centre of pressure, Sway path, Force plate

INTRODUCTION

Postural instability is a common manifestation following damage to the ligamentous complex of the ankle [8-9]. Inversion ankle injuries are a frequent sporting injury that leads to chronic pain, swelling, and functional instability (FI) [10-11] and is responsible for a substantial percentage of clinical referrals and emergency room visits annually [8-9]. Inversion ankle injuries often result in the development of FI and this was first described by Freeman [12] as the subjective feeling of the ankle 'giving way' after an inversion injury had been sustained. While this definition has been expanded upon as the research has progressed, FI still remains poorly defined but is usually applied to persons experiencing multiple episodes of instability as well as repetitive sprains with little or no external provocation [8-9]. FI is due, in part, to altered neuromuscular control, such as impaired reflexes, neuromuscular firing patterns, nerve conduction velocity and proprioception as well as losses in strength, power and endurance [8-10]. Current research suggests that the proprioceptive loss that occurs with FI may be a major factor in the high recurrence rate of inversion ankle injuries, which some estimate to be as high as 80% [9].

Evidence suggests that there is a link between proprioceptive deficits and reduced postural control as demonstrated by increased postural sway during unilateral stance [13-15]. Further, there is a general consensus that proprioceptive or balance exercises represent an important component of the rehabilitation of inversion ankle injuries [8-9]. These exercises typically challenge the sensory-motor pathways within the central nervous system (CNS). The processing of this information by
the CNS enables a coordinated and well executed motor response from cortical and spinal centres that control movement [60]. There is a significant body of literature that has examined the effectiveness of proprioceptive training, demonstrating improved postural control [4, 11, 12]. Pintsar et al. [15], demonstrated that 8 weeks of balance training on a Dura Disc improved postural control in subjects with ankle instability. Tropp et al. [50], Bernier and Perrin [51] and Kidgell et al. [55] all reported that postural control was improved after 6 weeks of balance training. Whilst the latter two studies provided specific information on training variables (i.e. duration of training time, exercise progression), there is only one study that has examined the effect of training volume on postural control. Puls and Gribble [57] compared the effect of 3 days versus 5 days of Thera-Band® (Hygenic Corp) training on postural control. They found no difference in postural control between groups after the 6 week training intervention. The only training variable manipulated in this study was the number of training days, there was no manipulation of other important training variables, such as progressive overload (i.e. increase in sets and repetitions), or functional progressions in the exercises prescribed.

Despite previous studies [4, 11, 12] demonstrating improvements in postural control, faster muscle reaction times, and increases in strength and endurance, ankle instability has still been found to exist 18 months after intensive rehabilitation [9]. This high recurrence rate may, in part, be attributed to inadequate exercise prescription, i.e. exercise selection, functional progression of exercises, number of sets and repetitions (volume) and training load progressions. Therefore, the purpose of the present investigation was to determine whether 8 weeks of high volume or low volume Dura Disc (Aquatic Health, Australia) training decreases postural sway. Further, given that the majority of ankle rehabilitation research has been conducted on wobble-boards, we also investigated the effects of a new rehabilitation device, the Dura Disc, as this has anecdotally been suggested to provide the same proprioceptive demand as other balance training devices. Further, this will be the first study to exclusively examine the clinical benefits of such a device.

**MATERIAL AND METHODS**

**Organisation of the Study**

An experimental study incorporating a randomised controlled design was employed. Seventeen subjects were randomly divided into one of the three following groups: High volume training (HVT, n = 5; 4 male and 1 female), Low volume training (LVT, n = 6; 5 male and 1 female) or Control group (CG, n = 6; 5 male and 1 female). Those subjects assigned to HVT or LVT completed 8 weeks of proprioceptive training on a Dura disc. The CG completed no specific balance training; however, they were instructed to maintain their current daily activities throughout the 8 week training period.

**Participants**

Subjects who had sustained a lateral ankle sprain (LAS) within the past 18 months volunteered to take part in the study. Subjects were recruited from the University population, physiotherapy and podiatry clinics as well as from expressions of interest by the public. Subjects were included if they had sustained a LAS within the past 18 months, had sufficient ankle joint mobility and function to perform normal weight bearing activities, and were aged between 18 and 35 years. Subjects that were still experiencing recurrent ankle joint pain and swelling or had limited range of movement within the ankle complex were excluded from the study. Further exclusion criteria included subjects that were currently undertaking any ankle rehabilitation or core stability training programs, had sustained a medial ankle sprain within the past 18 months, or suffered from any neurological disorder affecting the upper or lower extremities. The Deakin University human research and ethics committee approved the project. Table 1 outlines the subjects’ demographics.

**Table 1: Subjects’ Demographics**

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 5)</th>
<th>LVT (n = 6)</th>
<th>HVT (n = 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td>24.8 ± 6.93</td>
<td>23.3 ± 4.91</td>
<td>24.2 ± 5.04</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>183.3 ± 16</td>
<td>184.3 ± 16</td>
<td>184.2 ± 17</td>
</tr>
<tr>
<td><strong>Body mass (kg)</strong></td>
<td>82.8 ± 16</td>
<td>81.3 ± 15</td>
<td>81.9 ± 16</td>
</tr>
</tbody>
</table>

LVT: Low volume training, HVT: High volume training, n: sample size, SD: standard deviation, cm: centimetres, kg: kilograms

**PROCEDURES**

**Postural Control Assessment**

Postural control measures were obtained in accordance by Kidgell et al. [55]. Briefly, subjects were required to position themselves on top of a force plate with their eyes closed and shoes off and maintain their balance on one leg.
the leg that had sustained an ankle inversion injury for 25 seconds. The non-supporting limb was flexed at the knee and held approximately 90° and was not allowed to make contact with either the contralateral supporting limb or the ground during testing. The subject’s upper limbs were positioned across their chest. If the non-supporting limb made contact with the ground, the trial was aborted and was repeated after a 3 minute recovery period. The limb that had sustained the ankle inversion injury was tested three times with an intra-trial recovery of 3 minutes. The average maximum excursion of the centre of pressure (COP) for the three trials for each subject was calculated and the data was then used to determine the mean values for each group. This testing protocol was followed for both pre and post testing, with post testing conducted no more than 5 days after the program was completed and at approximately the same time of day as the initial test to ensure consistency. Subjects were also instructed to avoid any strenuous physical activity for at least 24 hours prior to the testing period.

Data was sampled at 75 Hz for 25 seconds and the movement of COP (the centre of the distribution of the total force applied to the supporting surface) of the body was examined for pre and post-test analysis [24, 26]. The COP was determined as the point of application of the ground reaction force vector on the force plate surface. COP was then separated into the anterior-posterior (AP) and medio-lateral (ML) direction. The custom written software on the force plate performed the computations and was manually triggered by the researcher once the subject assumed the single leg stance on top of the force plate [26, 28]. Reliability analysis indicated that the maximum ML sway was the most reliable measure \( r = 0.842, P = 0.009 \). Reliability analysis was conducted to ascertain the test-retest profile of the custom written software that calculated the parameters of COP and centre of mass (COM). Furthermore, errors for COP obtained via a force plate have been reported within the literature [29], therefore, it was necessary to ascertain and ensure that the measurements of COP were in fact reliable. The mean value of the three trials was determined and subsequently analysed for sway path, which was represented as the maximum distance travelled by the COP over the three trial periods and was expressed in millimetres (mm) [26, 28].

Dura Disc Training Procedures

Single leg stance with distraction (IA), 4-point star with opposite leg (1B). The 4-point star with opposite leg involved hip flexion, extension, abduction and adduction. This exercise creates a perturbation to the Dura Disc that challenges the dynamic stabilisation system of motor control.

![Fig. 1: Exercises Completed on the Dura Disc](image)

The training program consisted of nine exercises that were to be completed over an 8 week training period. This training duration was chosen as it was in accordance with other training studies that have used a similar training period of between 4 and 10 weeks [28, 29, 30, 31]. A progressive overload approach was taken with the degree of proprioceptive demand gradually increasing over the 8 weeks. The exercises chosen were all closed-chain in nature and were specific to training the musculature of the hip, talocrural and subtalar joints (as these are both affected during LAS) (see figure 1A & 1B). To increase the proprioceptive demand of these exercises they were all completed on a Dura Disc (AOK Health, Australia) throughout the entire 8 week intervention.

Previous research [12] has quantified training volume only by training time (minutes per day), whereas our study aims were to use an excise prescription model to determine and quantify training volume through "sets and repetitions" [30]. Table 1 illustrates this approach as well as describing the progressive overload used and differences between HVT and LVT programs.

Both training groups completed the same closed chain exercises 3 times per week for 8 weeks; however, they were performed at different volumes, as the aim was to investigate whether a HVT or LVT program would cause a greater change in postural sway. With both
groups completing the same closed chain exercises, the adaptations that occurred during the 8 week period can be attributed to the volume of training (i.e. sets and repetitions) completed and not the difference in exercises, as different exercises generally require different neural strategies therefore producing different training responses.

The training volume for both groups was increased every second microcycle as shown in Table 2. The exercises for week 1 and 2 included a single limb stance, controlled inversion/eversion and controlled plantarflexion/dorsiflexion. The principle of progressive overload was applied during weeks 3 and 4 and consisted of an increase in training volume and progression in exercise complexity. The following exercises were completed; single limb stance, single leg squat and 4-point star. Weeks 5 and 6 consisted of another increase in training volume and exercise progression with the following exercises being completed; single limb stance, 3/4 squat to raise (plantarflexion), single leg hip hikes. Weeks 7 and 8 consisted of a single limb stance with eyes closed, 4-point star with the contralateral limb and a single limb stance with distraction. The distraction task involved bouncing a ball from one side to the other in a continuous manner. All these exercises were completed in a unilateral closed-chain position to encourage proximal hip stabilisation, which is an important component of balance ability.

The changes in training volume between the groups was used as a process of improving muscle endurance in the musculature of the talocrural and subtalar joints, while the introduction of closing the eyes and progressively increasing the complexity of the exercises overloaded the proprioceptive system.

Statistical Analyses
Means and standard deviations were calculated for the parameters obtained from the force plate, specifically, the maximum COP excursion in the ML direction. Intraclass correlation coefficient (ICC) was used to determine the inter-trial reliability of the ML and AP COP excursion. With exclusion criteria creating smaller sample size, non-parametric Wilcoxon Signed Ranks and Kruskal-Wallis one-way ANOVA; and Cohen’s d effect size (ES) analyses, with Hedge’s g adjustment for sample size, were used to compare the effect of training volume on postural sway between the HVT and LVT groups. For all comparisons, a significance level of P < 0.05 was employed and ES conventions were used for small (0.25), medium (0.5) and large (0.8) comparative effects.

RESULTS
Force Platform Data
Figure 2 displays the mean maximum COP excursion in the ML direction obtained from the force plate for each experimental group for the pre and post testing conditions. The maximum COP excursion in the ML direction did not vary between pre-test and post-test conditions for the control group (mean COP excursion, pre 88.84 ± 24.67 and post 83.56 ± 24.08; Table 3). There was a significant (P < 0.01) difference in postural sway between pre and post testing for both the LVT (pre

<table>
<thead>
<tr>
<th>Week</th>
<th>Exercise</th>
<th>LVT</th>
<th>HVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 &amp; 2</td>
<td>Single leg stance</td>
<td>Sets: 2, Reps: 20s</td>
<td>Sets: 3, Reps: 20s</td>
</tr>
<tr>
<td></td>
<td>Controlled inversion/eversion</td>
<td>Sets: 2, Reps: 10</td>
<td>Sets: 2, Reps: 15</td>
</tr>
<tr>
<td></td>
<td>Controlled plantarflexion/dorsiflexion</td>
<td>Sets: 2, Reps: 10</td>
<td>Sets: 2, Reps: 15</td>
</tr>
<tr>
<td>3 &amp; 4</td>
<td>Single leg stance</td>
<td>Sets: 2, Reps: 30s</td>
<td>Sets: 3, Reps: 30s</td>
</tr>
<tr>
<td></td>
<td>Single leg squat</td>
<td>Sets: 2, Reps: 15</td>
<td>Sets: 4, Reps: 10</td>
</tr>
<tr>
<td></td>
<td>4-point star</td>
<td>Sets: 2, Reps: 15</td>
<td>Sets: 4, Reps: 10</td>
</tr>
<tr>
<td>5 &amp; 6</td>
<td>Single leg stance</td>
<td>Sets: 3, Reps: 30s</td>
<td>Sets: 3, Reps: 35s</td>
</tr>
<tr>
<td></td>
<td>3/4 squat to raise</td>
<td>Sets: 4, Reps: 10</td>
<td>Sets: 3, Reps: 17</td>
</tr>
<tr>
<td></td>
<td>Single leg hip hike</td>
<td>Sets: 4, Reps: 10</td>
<td>Sets: 3, Reps: 17</td>
</tr>
<tr>
<td>7 &amp; 8</td>
<td>Single leg stance (eyes closed)</td>
<td>Sets: 2, Reps: 20s</td>
<td>Sets: 2, Reps: 30s</td>
</tr>
<tr>
<td></td>
<td>4-point star with opposite leg</td>
<td>Sets: 4, Reps: 12</td>
<td>Sets: 4, Reps: 15</td>
</tr>
<tr>
<td></td>
<td>Single leg stance with distraction</td>
<td>Sets: 4, Reps: 12</td>
<td>Sets: 4, Reps: 15</td>
</tr>
</tbody>
</table>

LVT; Low volume training, HVT; High volume training, Reps; repetitions, s, seconds.

Castricum et al.
High Volume Versus Low Volume Balance Training on Postural Sway in Adults with Previous Ankle Inversion Injury

= 88.69 mm ± 25.08 mm, post = 72.17 mm ± 27.53 mm; ES = 0.6; Table 3) and HVT (pre = 77.47 mm ± 10.57 mm, post = 58.54 mm ± 7.01 mm; ES = 1.7; Table 3) groups. Wilcoxon Signed Ranks test demonstrated a significant time difference in sway path in pre- and post-testing conditions and training group. However, analysis of time and group effects, using Kruskal-Wallis one-way ANOVA, showed no significant difference in treatment effect between both training group (LVT and HVT) and postural sway.

Fig. 2: Mean Changes in ML Cop Excursion Before and after Balance Training

DISCUSSION

The purpose of the present investigation was to compare the exercise prescription effect of high and low volume training on postural control in subjects with a history of ankle inversion injuries. This preliminary data suggests that both high and low volume balance training is effective in improving postural sway, however, given the small sample sizes, caution should be exercised when generalising the findings, particularly insofar of the fact that the participants in this study were subject to stringent inclusion/exclusion criteria. Although there were no statistical differences between training group and postural sway, and both HVT and LVT programs showed significant improvements (p < 0.01), the effect size differences between pre and post training periods, intimate that higher training volumes may be superior than lower training volumes (HVT, ES = 1.7; LVT, ES = 0.5). These preliminary findings are important as this is one of only two studies that have attempted to address the importance of training volume in the rehabilitation of ankle injuries. The present findings are in contrast to Puls and Gribble [27] who examined the effect of Theraband® training, performed either 3 or 5 times a week for 6 weeks on postural control. They reported no change in postural control after the training intervention in either group. The difference between the studies may in part be attributed to the types of exercises prescribed, the pattern of overload and the number of sets and repetitions prescribed.

In the present investigation, we prescribed a variety of exercises that gradually increased in complexity. Further, it could be suggested that a balance training program that challenges the dynamic stabilisation systems of motor control [19] through unpredictable perturbations (as provided by Dura Disc) may be more beneficial than traditional balance training exercises. Puls and Gribble [27] prescribed only one exercise throughout the 6 week training period and there was no manipulation of training volume (sets x repetitions, unpredictable perturbations) other than a progressive increase in resistance. The present study employed a range of exercises that integrated the hip and ankle musculature in a close chain position on a Dura Disc. We suggest that the exercises completed challenged the dynamic stabilisation system of motor control through unpredictable perturbation, provided by the Dura Disc.

The approach to utilize dynamic exercises that integrate the hip and ankle was based upon previous studies that have demonstrated that persons with ankle instability utilize a different postural control strategy when compared to healthy controls [8, 9, 10]. For example, Tropp and Odenrick [10] reported that subjects with ankle

| Table 3: Pre-test and Post-test Data for Postural Sway in ML Direction |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Mean Value (mm) | Maximum Value (mm) | Minimum Value (mm) | SE (mm) | SD (mm) |
| Pre | Post | Pre | Post | Pre | Post | Pre | Post |
| **Control** | | | | | | | |
| 88.84 | 83.56 | 131.86 | 128.05 | 60.07 | 62.02 | 10.07 | 9.83 | 24.67 | 24.08 |
| **LVT** | | | | | | | | |
| 88.69 | 72.17 | 120.38 | 121.82 | 63.16 | 41.68 | 10.24 | 11.24 | 25.08 | 27.53 |
| **HVT** | | | | | | | | |
| 77.47 | 58.54 | 90.86 | 66.93 | 62.41 | 50.69 | 4.73 | 3.14 | 10.57 | 7.14 |

LVT: Low volume training, HVT: High volume training, mm, millimetres; SE, standard error, SD, standard deviation
instability had a greater maximum COP excursion and displayed a greater tendency to utilize the hip joint when correcting postural control. Using a hip strategy to correct postural control would result in greater torque production through the subtalar joint, thus increasing COP excursion in the ML axis [9]. Due to the specificity of the exercises prescribed, the changes in postural sway seen within the present study may have been due to improved pelvic stabilization, therefore reducing the reliance of the hip joint to be utilized during postural control correction.

Although no spatiotemporal analysis of the COP data points were obtained in the present study, it could be suggested that the improvements in maximum COP excursion in both the HVT and LVT may have been due to improved total-time-to-boundary (TTB) [8, 9]. There is convincing evidence to suggest that subjects with ankle instability have less time to make postural corrections to maintain postural sway, suggesting that they have a constrained sensorimotor system [9]. Therefore, it is possible that the changes observed in maximum COP excursion in the ML direction was due to some aspect of sensorimotor control (more so in the HVT compared to LVT). However, we can only speculate on this, as TTB measures were not obtained.

Increasing the training load every second microcycle may have contributed to improved muscular endurance of the hip and ankle, thus improving postural control. Previous investigations have reported that persons with ankle instability have a lower level of muscular endurance within the muscles that avert, invert, dorsiflex and plantarflex the foot and ankle [6, 10, 11].

Recent evidence suggests that patients with ankle instability do not have clinical symptoms of hypermobility; rather they have a loss of neuromuscular control, especially delayed reflex activity. Ellis et al. [9] reported that 6 weeks of proprioceptive balance training improved peroneal reaction time. Santilli et al. [46] demonstrated reduced peroneal activation during stance phase of the gait cycle only among those with ankle instability. Due to the progressive complexity (unpredictable perturbations and challenges to the dynamic stabilization control system) of the exercises prescribed in the present study, it is possible that the reduction in postural sway in the ML direction was due to improved recruitment of the peroneal musculature, thus increasing the subjects’ time to make postural corrections. This effect may have been greater in the HVT group compared to the LVT. Osborne et al. [48] demonstrated that 8 weeks of ankle disc training reduced onset latency in the peroneal musculature. Improved peroneal activation would prevent excessive lateral postural sway outside the base of support, therefore reducing the inversion moment [49].

It is interesting to note that within the strength training literature, training volume is well described. For example, there are implicit guidelines for hypertrophy, maximum strength and power development, however, the prescription of rehabilitation exercises for the ankle is ad-hoc [48]. We have attempted to address this question; however because of the lack of research on exercise volume for ankle rehabilitation, the training volume prescribed in the present study was based upon our previous work [46]. In light of this, the effect size changes suggest that training volume is important for postural control.

CONCLUSION

The present study has demonstrated that 8 weeks of proprioceptive training improves postural control among persons with a history ankle injury. While this is only preliminary data, reported effect sizes suggest that HVT may be more effective than LVT. These findings may have a clinical benefit as it demonstrates that training volume plays a role in the exercise prescription process of persons with a history of ankle injury.

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