

# Systematic Review of Postural Control and Lateral Ankle Instability, Part II: Is Balance Training Clinically Effective?

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**Objective:** To answer the following clinical questions: (1) Can prophylactic balance and coordination training reduce the risk of sustaining a lateral ankle sprain? (2) Can balance and coordination training improve treatment outcomes associated with acute ankle sprains? (3) Can balance and coordination training improve treatment outcomes in patients with chronic ankle instability?

**Data Sources:** PubMed and CINAHL entries from 1966 through October 2006 were searched using the terms *ankle sprain*, *ankle instability*, *balance*, *chronic ankle instability*, *functional ankle instability*, *postural control*, and *postural sway*.

**Study Selection:** Only studies assessing the influence of balance training on the primary outcomes of risk of ankle sprain or instrumented postural control measures derived from testing on a stable force plate using the modified Romberg test were included. Studies had to provide results for calculation of relative risk reduction and numbers needed to treat for the injury prevention outcomes or effect sizes for the postural control measures.

**Data Extraction:** We calculated the relative risk reduction and numbers needed to treat to assess the effect of balance

training on the risk of incurring an ankle sprain. Effect sizes were estimated with the Cohen *d* for comparisons of postural control performance between trained and untrained groups.

**Data Synthesis:** Prophylactic balance training substantially reduced the risk of sustaining ankle sprains, with a greater effect seen in those with a history of a previous sprain. Completing at least 6 weeks of balance training after an acute ankle sprain substantially reduced the risk of recurrent ankle sprains; however, consistent improvements in instrumented measures of postural control were not associated with training. Evidence is lacking to assess the reduction in the risk of recurrent sprains and inconclusive to demonstrate improved instrumented postural control measures in those with chronic ankle instability who complete balance training.

**Conclusions:** Balance training can be used prophylactically or after an acute ankle sprain in an effort to reduce future ankle sprains, but current evidence is insufficient to assess this effect in patients with chronic ankle instability.

**Key Words:** ankle sprains, chronic ankle instability, injury prevention, stabilometry

Balance and coordination training are common components of intervention programs for the prevention and treatment of acute lateral ankle sprains and chronic ankle instability (CAI).<sup>1,2</sup> In 1965, Freeman<sup>3</sup> and Freeman et al<sup>4</sup> hypothesized that balance and coordination training could diminish proprioceptive deficits associated with ligamentous injury to the ankle. Contemporary theory suggests that balance and coordination training may have both local and central effects on the sensorimotor system.<sup>5–9</sup> Although balance and coordination training has become standard care in the treatment of ankle instability, consensus is lacking regarding the clinical evidence of the efficacy and effectiveness of these interventions. A thorough quantitative review of this body of literature will allow clinicians to make more informed, evidence-based clinical decisions regarding balance training in patients with ankle instability. Therefore, the purposes of this systematic review were to answer the following clinical questions: (1) Can prophylactic balance and coordination training reduce the risk of suffering a lateral ankle sprain? (2) Can balance and coordination training improve treatment outcomes associated with acute ankle sprains? (3) Can balance and coordination training improve treatment outcomes in patients with CAI?

## METHODS

### Search Strategy

We searched PubMed and CINAHL entries from 1966 through October 2006 using the terms *ankle sprain*, *ankle*

*instability*, *balance*, *chronic ankle instability*, *functional ankle instability*, *postural control*, and *postural sway*. Relevant articles were also identified by cross-referencing the citation lists of articles identified in the electronic search. A total of 146 articles were identified (Figure 1).

### Criteria for Selecting Studies

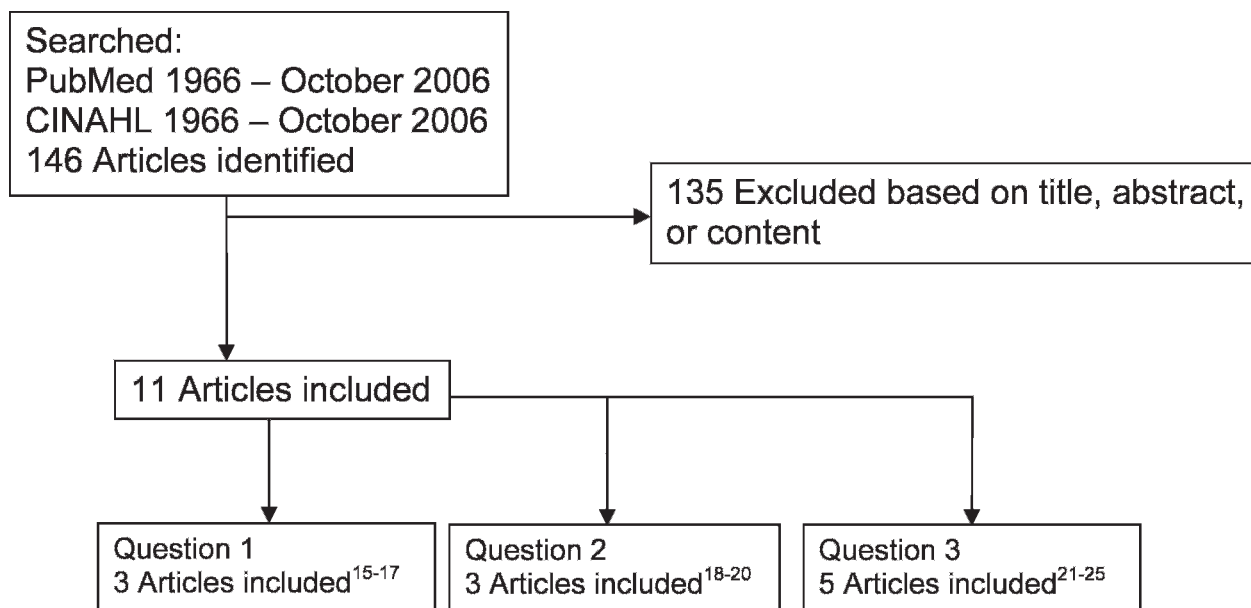
To be included, a study had to address at least 1 of the 3 clinical questions stated above and provide adequate results for calculation of effect sizes for instrumented postural control measures in the modified Romberg position on a stable force plate or calculation of relative risk reduction (RRR) and numbers needed to treat (NNT) for the prevention of incident or recurrent ankle sprains where applicable.

### Assessment of Methodologic Quality

Included studies were evaluated using the PEDro scale,<sup>10</sup> a 10-point assessment tool used to evaluate the methodologic quality of original research articles. Consensus regarding the PEDro score for each article was agreed upon by both authors. A higher PEDro score indicates higher-quality study design.

### Data Extraction and Statistical Analysis

For the assessment of preventive effects of balance and coordination training, we calculated 2 types of effect



**Figure 1.** Flow chart for selecting articles to be included in the systematic review to answer our 3 questions. Article reference numbers are superscripted.

measures based on the epidemiologic data reported in the original articles. To assess the preventive effects of balance and coordination training programs, RRR, NNT, and their 95% confidence intervals (CIs) were computed.

The RRR estimates the percentage of injury risk that is reduced for individuals who participate in an intervention program versus individuals in the control group.<sup>11</sup> When the lower boundary of an RRR CI crosses zero, a reduction in the risk of ankle sprain for the intervention group is not present. Conversely, when the lower boundary of a RRR CI is greater than 0, a reduction in the risk of ankle sprain is present for the intervention group compared with the control group.

The NNT estimates how many individuals need to participate in an intervention program to prevent 1 injury.<sup>11</sup> A positive NNT value indicates a beneficial preventive effect due to the intervention, whereas a negative value indicates a potential harmful effect from the intervention (ie, increased injury risk). Positive NNT values were described as NNT to benefit (NNTB) and negative values as NNT to harm (NNTH).<sup>12</sup> If no preventive effect was present, then the NNT values approached infinity ( $\infty$ ), indicating that no preventive effect occurred and that an infinite number of individuals would have to be treated to benefit from the intervention.<sup>12</sup>

To evaluate the rehabilitative effects of balance and coordination training on acute ankle sprains and CAI, we calculated 3 types of measures. The RRR, NNT, and their respective 95% CIs were computed based on injury recurrence data. For instrumented postural control measures and self-reported function scores, effect size (Cohen *d*) and 95% CIs were estimated (1) between the measures of the balance training group and control groups, (2) within pretraining and posttraining measures in the groups that underwent balance and coordination training, and (3) within the involved and uninvolved limbs in those with unilateral acute ankle injuries who underwent rehabilitation. Not all comparisons could be made from all included studies. The strength of effect sizes was interpreted using

the guidelines described by Cohen,<sup>13</sup> with values less than 0.4 interpreted as weak, from 0.41 to 0.7 as moderate, and more than 0.7 as strong.

Lastly, the quality of evidence used to answer each of the 3 questions was assessed using the Strength of Recommendation Taxonomy (SORT).<sup>14</sup> The SORT level of recommendations range from 1 to 3, with 1 indicating good-quality, patient-oriented evidence; 2 indicating limited-quality, patient-oriented evidence; and 3 indicating non-patient-oriented evidence. The SORT strength of recommendations range from A through C, with A indicating that the recommendation is based on consistent and good-quality, patient-oriented evidence; B that it was based on inconsistent or limited-quality, patient-oriented evidence; and C that it was based on evidence other than patient-oriented evidence.<sup>14</sup>

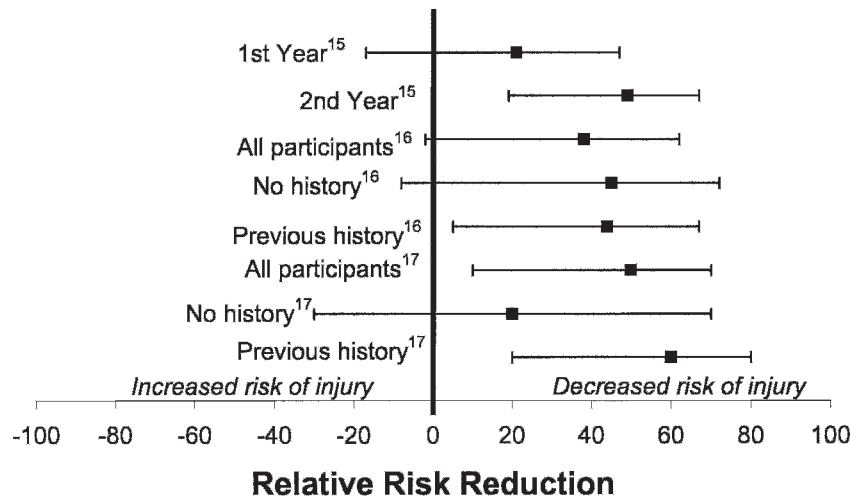
## RESULTS

### Can Prophylactic Balance Training Reduce the Risk of Sustaining a Lateral Ankle Sprain?

Three articles<sup>15-17</sup> met the inclusion criteria to answer this question (Table 1). The mean PEDro score for these articles was 6.0, and all 3 articles<sup>15-17</sup> provided sufficient data to allow calculation of RRR and NNT. The point measures of the RRR ranged from a 20% to 60% reduction in the risk of sustaining an ankle sprain after undergoing balance and coordination training. Four of the 8 comparisons shown in Figure 2 had 95% CIs that crossed 0. Of these, 1 represented athletes who underwent the first year of a 2-year balance training intervention.<sup>15</sup> The other 3 represented athletes without a history of previous ankle sprain<sup>16,17</sup> and a group including individuals with and without histories of ankle sprain.<sup>16</sup> The 4 comparisons in Figure 2 showing reductions in ankle sprain risk with prophylactic balance training involved athletes who had a history of ankle sprain,<sup>16,17</sup> a group that included athletes with and without history of a sprain,<sup>17</sup> and athletes who

**Table 1. Characteristics of Articles Used to Answer the Question, “Can Prophylactic Balance and Coordination Training Reduce the Risk of Ankle Sprain?”**

Authors	PEDro Score	Study Design	Study Population	Intervention	No. of Injuries Sprains/No Sprains	Frequency	Duration	Supervision
Bahr et al <sup>15</sup>	5	Prospective cohort	Elite male volleyball players	1. Proprioceptive training with a balance board 2. Technical training focusing on jumping and landing techniques	1992–1993: 48/225 1993–1994: 38/235 1994–1995: 24/244	Not specified	Not specified	Not specified
McGuine and Keene <sup>16</sup>	7	Randomized controlled trial	High school male and female basketball and soccer players	5-Phase balance training program 5-Phase balance training program	All participants: training 23/350 control 39/353 Previous history: training 11/78 control 16/77 No history: training 12/272 control 23/276	Phase 1–4: 5 sessions/wk Phase 5: 3 sessions/wk	Phase 1–4: 4 wk Phase 5: Throughout competitive season	Athletic trainer
Verhagen et al <sup>17</sup>	6	Randomized controlled trial	Community-based male and female volleyball players	Balance board training program	All participants: training 29/612 control 41/445 Previous history: training 19/400 control 31/308 No history: training 10/212 control 10/137	4 sessions/wk	36 wk	Coaches at each practice session; physician and physical therapist evaluation once during the season

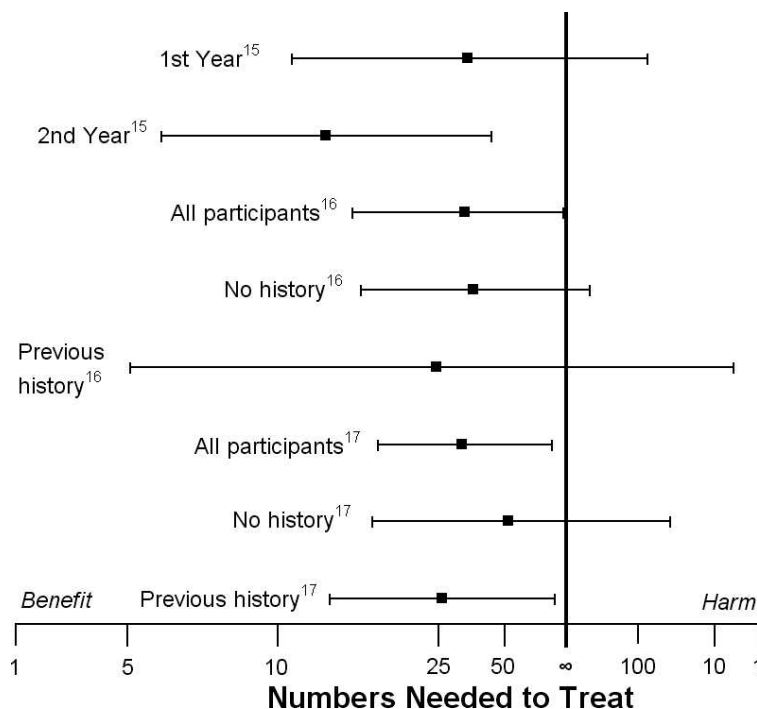


**Figure 2.** Can prophylactic balance and coordination training reduce the risk of ankle sprain? Relative risk reduction and 95% confidence intervals reported for all studies. High-quality randomized controlled trials by Verhagen et al<sup>17</sup> and McGuine and Keene<sup>16</sup> yielded results indicating a reduction in the risk of ankle sprain, especially in those with a history of ankle sprain. Article reference numbers are superscripted.

were in the second year of a 2-year training intervention.<sup>15</sup> After undergoing prophylactic balance training, athletes with a history of ankle sprains had a consistent and significant reduction in the risk of sustaining recurrent sprains.<sup>16,17</sup>

The NNT point estimates for the various comparisons ranged from 12 to 44 NNTB (Figure 3). Four of the 8 comparisons had CIs that crossed infinity, indicating uncertainty as to the nature of the preventive effect. These comparisons were among groups representing athletes without a history of ankle sprain,<sup>16,17</sup> a group

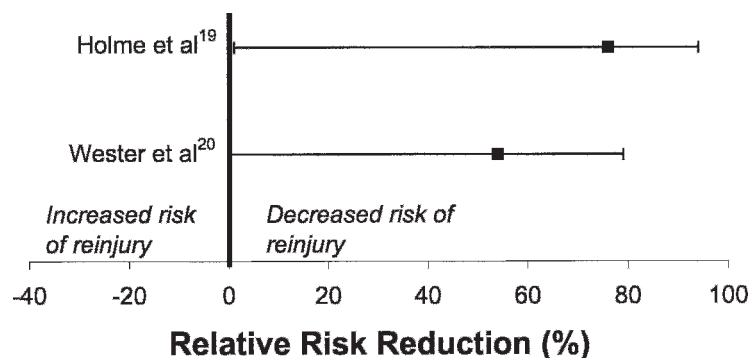
that included athletes with and without a history of sprain,<sup>16</sup> and athletes who underwent the first year of a 2-year balance training intervention.<sup>15</sup> The 95% CIs around these point estimates ranged from 6 NNTB to 10 NNTH. Based on this evidence, it appears that for those with a history of sprain, prophylactic balance training reduced the risk of subsequent ankle sprains. The SORT level of evidence was 1, with a grade of recommendation of A. Evidence is inadequate to show that balance training is effective in preventing incident ankle sprains in athletes without prior injury. For this



**Figure 3.** Can prophylactic balance and coordination training prevent ankle sprain injury? Numbers-needed-to-treat analysis with 95% confidence intervals revealed that in order to prevent 1 ankle sprain, 12 to 44 athletes would have to be treated every year. The benefit is most apparent for those who have a history of ankle sprain or who have participated in 2 years of a training program. Article reference numbers are superscripted.

**Table 2. Characteristics of Articles Used to Answer the Question, “Can Balance and Coordination Training Improve Treatment Outcomes After Lateral Ankle Sprain?”**

Authors	PEDro Score	Study Design	Inclusion Criteria	Training Group	Control Group	Intervention	Frequency	Duration	Supervised	Follow-up
Goldie et al <sup>18</sup>	5	Prospective cohort	Males and females with acute lateral ankle sprain and no history of previous injury Positive anterior drawer sign Normal radiographs	10 males 14 females	17 males 7 females	Rocker board	32 practice sessions (range, 2 to 140)	Not specified	No	Not specified
Holme et al <sup>19</sup>	8	Randomized controlled trial	Male soccer players with history of lateral ankle sprain and functional instability of 1 or both ankles	17 males 12 females	27 males 15 females	Balance exercises for both legs, figure-8 running, standing on balance board and catching a ball, standing on outside of feet with eyes open and closed Wobble board training	Twice/wk	1 h	Yes: physical therapy rehabilitation clinic	6 wk, 4 mo, 1 year
Wester et al <sup>20</sup>	7	Randomized controlled trial	Males and females with grade 2 ankle sprain who previously had participated in 2 h of physical activity/wk	24 individuals (sex not specified)	24 individuals (sex not specified)		Daily for 12 wk	15 min	No	Average of 230 d



**Figure 4. Can balance and coordination training improve treatment outcomes after lateral ankle sprain? Relative risk reduction and 95% confidence intervals are reported for recurrence of ankle injury after undergoing balance training. Holme et al<sup>19</sup> had a follow-up period of 12 months (SD not reported) and Wester et al<sup>20</sup> had a mean follow-up period of 230 ( $\pm 62.9$ ) days. The risk of ankle reinjury after sustaining an acute lateral ankle sprain was reduced in those who underwent balance training. Article reference numbers are superscripted.**

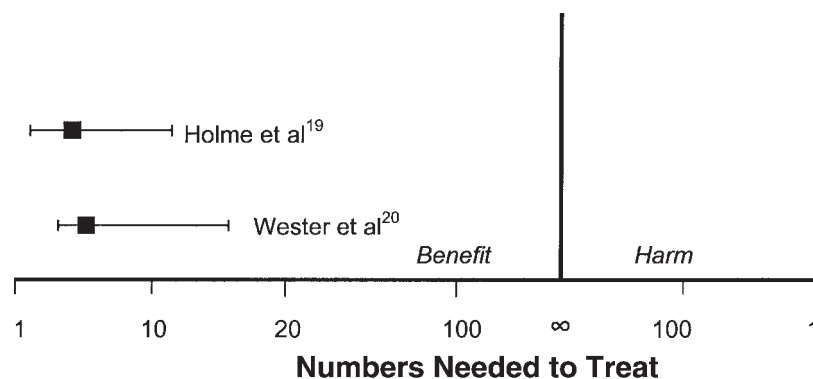
intervention, the SORT level of evidence was 2, with a grade of recommendation of B.

### Can Balance and Coordination Training Improve Treatment Outcomes Associated With Acute Ankle Sprains?

The characteristics of the 3 articles<sup>18–20</sup> that met the inclusion criteria to answer this question are detailed in Table 2. The mean PEDro score for these articles was 4.7. Two articles<sup>19,20</sup> allowed for RRR and NNT calculations (Figures 4 and 5). These articles revealed point estimates of 54% to 76% RRR of sustaining recurrent ankle sprain after undergoing balance training following an acute ankle sprain. The 95% CIs for the RRR did not cross zero and ranged from 0 to 94. The NNT analysis revealed that in order to prevent 1 recurrent ankle sprain, 4 to 5 patients recovering from acute ankle sprains would need to complete the rehabilitation training, with 95% CIs around these point measures ranging from 2 to 17 NNTB.

Two articles<sup>18,19</sup> allowed for calculation of effect sizes to compare postural control measures between the balance training group and control group, whereas one article<sup>19</sup> allowed for the effect size calculation between injured and uninjured sides and between pretraining and posttraining measures. The point measures of effect size for group comparisons between trained and untrained groups ranged from -0.21 to -1.3, with a negative value indicating that the balance training group had better postural control than the control group. The effect sizes ranged from moderately to strongly negative effect sizes; however, all CIs crossed zero, indicating uncertainty as to the true effect of balance training on postural control performance measures (Figure 6). Comparisons between the injured, trained limbs and uninjured limbs revealed effect sizes ranging from 0.17 to 3.73, with 3 of the 4 comparisons having CIs that crossed zero (Figure 7). A positive effect size indicated that the injured, trained limb had worse postural control measures than the uninjured limb. Thus, side-to-side deficits in postural control may have still been present in





**Figure 5.** Can balance and coordination training improve treatment outcomes after lateral ankle sprain? Numbers-needed-to-treat analysis with 95% confidence intervals revealed that in order to prevent the recurrence of 1 ankle sprain, 4 to 5 patients need to be treated with balance and coordination training. Article reference numbers are superscripted.

those who suffered an acute ankle sprain after they had undergone balance training.

Comparisons between pretraining and posttraining measures at 6 weeks and 4 months had effect sizes of  $-4.31$  and  $-2.73$ , respectively.<sup>19</sup> A negative effect size indicated that balance had improved after balance training compared with baseline measures. Although these effect size point estimates were very large, the CIs crossed zero, thus casting uncertainty on these findings. Whether improvements in instrumented postural control measures exist after balance training in those who sustain acute ankle sprain are unclear.

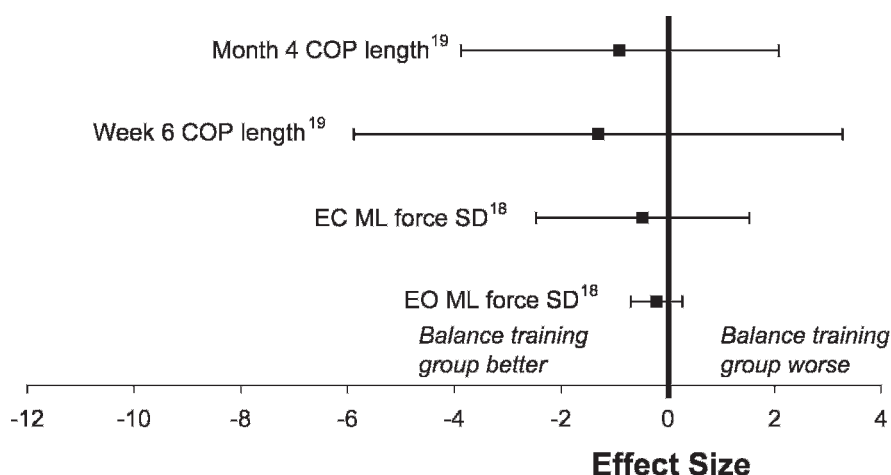
Based on this evidence, it appears that balance training after acute ankle sprain substantially decreased the risk of recurrent ankle sprains. For this finding, the SORT level of evidence was 1, with a grade of recommendation of A. However, evidence is inconclusive as to whether postural control improvements existed between the trained and untrained groups and injured and uninjured limbs and whether these effects in the trained limbs are lasting. For these comparisons, the SORT level of evidence was 2, with a grade of recommendation of B.

### Can Balance and Coordination Training Improve Treatment Outcomes Associated With Chronic Ankle Instability?

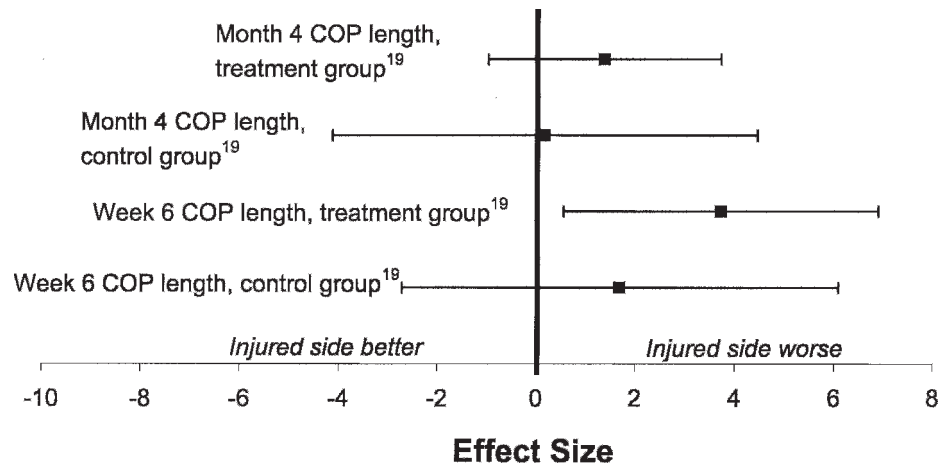
Five articles<sup>21–25</sup> met the inclusion criteria to answer this question (Table 3). The mean PEDro score for these articles was 5.2. None of the articles provided results to allow for the calculation of RRR or NNT.

Two sets of authors<sup>21,22</sup> examined group differences between CAI treatment groups and CAI controls who received no intervention. One study<sup>21</sup> examined differences between a training group and a group that received a sham treatment (electric stimulation). The group effect sizes ranged from  $-0.65$  to  $0.34$ , with a negative effect size indicating better postural control after training in the balance training group and a positive effect size indicating better postural control in the control/sham groups (Figure 8). Most of the effect sizes for group comparisons were negative and ranged from weak to moderate effects; however, several of the CIs around these point measures crossed zero.

Five sets of researchers<sup>21–25</sup> examined differences between pretraining and posttraining postural control mea-



**Figure 6.** Can balance and coordination training improve outcomes after lateral ankle sprain? Effect sizes and 95% confidence intervals are shown comparing those who underwent balance training after lateral ankle sprain with those who did not. Whether those who underwent balance training had improvements in postural control compared with those who did not is unclear. COP indicates center of pressure; EC, eyes closed; EO, eyes open; ML, mediolateral. Article reference numbers are superscripted.



**Figure 7.** Can balance and coordination training improve treatment outcomes after lateral ankle sprains? Effect sizes and 95% confidence limits are shown comparing postural control performance between injured and uninjured limbs in those who underwent rehabilitation after acute lateral ankle sprain with those who did not in the Holme et al<sup>19</sup> study. Whether postural control of the injured limb improved compared with the uninjured limb in those who participated in balance training after lateral ankle sprain is inconclusive. COP indicates center of pressure. Article reference numbers are superscripted.

sures in the involved limbs, and 1 group<sup>23</sup> also reported pretraining and posttraining measures in the uninjured limb in individuals with unilateral CAI. The effect sizes for pretraining to posttraining comparisons ranged from  $-2.85$  to  $-0.25$ , with a negative effect size indicating better postural control after training in the balance training group and a positive effect size indicating worse postural control after training compared with pretraining measures (Fig-

ure 9). Most of the effect sizes for these comparisons were negative and ranged from weak to strong effects; however, several of the CIs around these point measures crossed zero.

Based on this systematic review, no conclusive evidence indicates that balance training significantly improved postural control measures related to CAI. The SORT level of evidence was 2, with a grade of recommendation of B.

**Table 3.** Characteristics of Articles Used to Answer Question 3: Can Balance and Coordination Training Improve Treatment Outcomes Associated With Chronic Ankle Instability?

Authors	PEDro Score	Study Design	Inclusion Criteria	Involved Group	Comparison Subjects	Intervention	Duration	Frequency	Follow-Up
Bernier and Perrin <sup>21</sup>	7	Randomized controlled trial	History of at least 1 significant inversion ankle sprain followed by repeated injury and/or a feeling of instability and giving way	17 in experimental group	14 in control group 14 in sham group	Balance training on fixed surface and unstable surfaces	6 wk	3 d/wk 10 min/d	None
Eils and Rosenbaum <sup>22</sup>	6	Randomized controlled trial	History of repeated ankle sprains and a self-reported feeling of instability or giving way	6 males 14 females	6 males 4 females	Multistation balance training program	6 wk	1 d/wk 20 min/d	12 mo
Gauffin et al <sup>23</sup>	4	Prospective cohort	Functional ankle instability consisting of recurrent sprains and feeling of the ankle giving way	10 male soccer players	None	Ankle disk training	8 wk	5 d/wk 10 min/d	None
Rozzi et al <sup>24</sup>	5	Prospective cohort	Males and females with history of unilateral ankle sprain and residual symptoms; positive anterior drawer sign; normal radiographs	8 males 5 females	7 males 6 females (no history of ankle sprain)	Biodex Stability System (Shirley, NY)	4 wk	3 d/wk	None
Tropp et al <sup>25</sup>	4	Prospective cohort	Previous history of ankle sprain and functional ankle instability	10 male soccer players	None	Ankle disk training	6 wk	Daily for 15 min	None

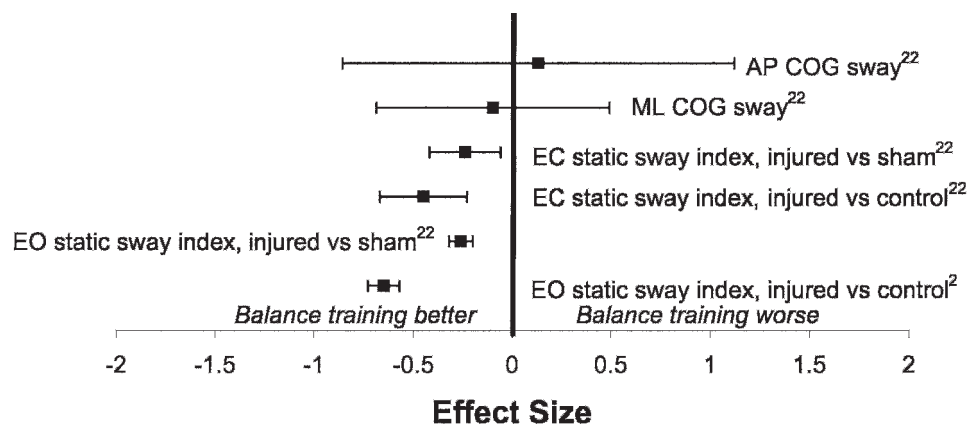


Figure 8. Can balance and coordination training improve treatment outcomes in those with chronic ankle instability? Effect sizes and 95% confidence intervals are shown for those who underwent balance training and those who did not with chronic ankle instability groups. The results of Tropp et al<sup>25</sup> are not shown here due to the large confidence intervals associated with the point measure of effect size (center of pressure area effect size = 2.20, 95% confidence interval = -38.08, 47.45). Whether postural control improved in those with chronic ankle instability compared with healthy controls is unclear. AP indicates anteroposterior; COG, center of gravity; ML, mediolateral; EC, eyes closed; EO, eyes open. Article reference numbers are superscripted.

## DISCUSSION

### Can Prophylactic Balance and Coordination Training Reduce the Risk of Sustaining a Lateral Ankle Sprain?

The preventive effect of balance training was shown in all studies, as demonstrated by significant RRRs for ankle sprains in those who completed the training programs.<sup>15-17</sup> The preventive effects were most apparent in those with a history of ankle sprain<sup>16,17</sup> and in those with 2 consecutive years of balance training.<sup>15</sup> In those with a history of ankle sprains, balance training was associated with RRRs for

recurrent ankle sprains of up to 60%.<sup>16,17</sup> Additionally, Bahr et al<sup>15</sup> showed a 49% reduction in the risk of ankle sprain in volleyball players during the second year of balance training compared with a 21% reduction during the first year of training. The CIs around the first-year point estimate crossed zero, indicating uncertainty as to the preventive effect, whereas those in the second year did not. This may indicate a cumulative effect for balance training, meaning that the longer the program is implemented, the greater its preventive effect. The Bahr et al<sup>15</sup> intervention also included volleyball-specific technical training and athlete education sessions, so all injury prevention effects may not be solely attributable to balance training.

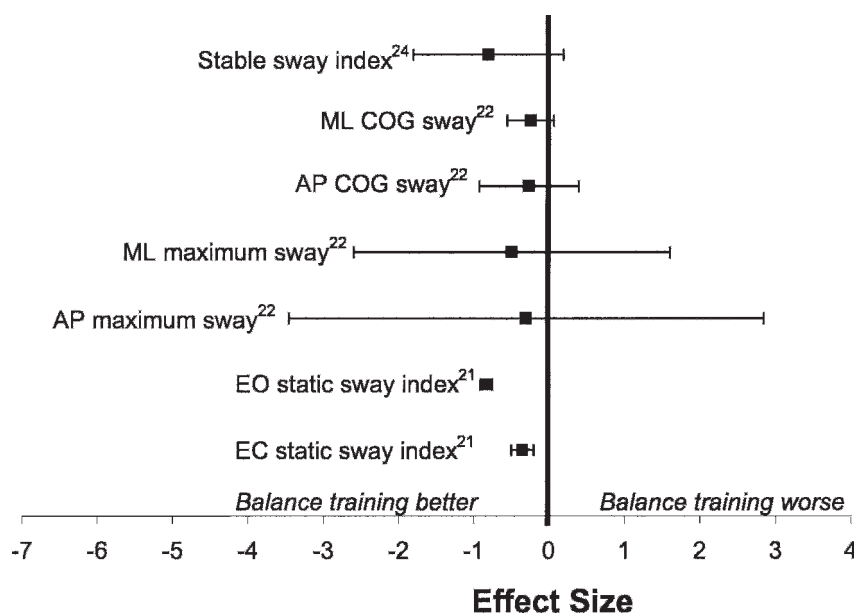


Figure 9. Can balance and coordination training improve treatment outcomes in those with chronic ankle instability? Effect sizes and 95% confidence intervals are shown for prebalance training and postbalance training postural control measures in those with chronic ankle instability. Whether postural control improved after balance training in those with chronic ankle instability is unclear. The result from Gauffin et al<sup>23</sup> (COP area effect size = -2.85, 95% confidence interval = -33.72, 36.57) and Tropp et al<sup>25</sup> (COP area effect size = -2.20, 95% confidence interval = -43.05, 47.45) are not displayed due to large confidence intervals around the effect size. ML indicates mediolateral; COG, center of gravity; AP, anteroposterior; EO, eyes open; EC, eyes closed. Article reference numbers are superscripted.



The NNT point estimates ranged from 12 to 44 NNTB, with 95% CIs that ranged from 2 NNTB to 10 NNTB. Volleyball, soccer, and basketball teams typically consist of 10 to 30 players each; thus, a balance training and coordination training program may need to be implemented for anywhere from 1 to 4 seasons to prevent 1 ankle sprain on a team. Clearly, however, the preventive effect of balance and coordination training is more pronounced in those with a history of ankle sprain. McGuine and Keene<sup>16</sup> and Verhagen et al<sup>17</sup> both found a greater preventive effect in those with a history of previous sprain. For the McGuine and Keene results,<sup>16</sup> the NNT 95% CI for those with a history of sprain just reached infinity, potentially indicating uncertainty as to how many athletes would need to be treated in order to prevent 1 ankle sprain. Yet the point estimate was 21 NNTB. This value was lower than when treating all athletes and those without a history of sprain in both studies, in which the NNT point measures ranged from 26 to 44 NNTB. The comparatively small sample size of this subset of athletes<sup>16</sup> with a history of ankle sprain (training group  $n = 89$ , control  $n = 93$ ) is likely responsible for the increased width of the CIs around this point estimate. With a larger sample size in each group, these confidence intervals might have narrowed around the Verhagen et al<sup>17</sup> point estimate (training group  $n = 419$ , control group  $n = 339$ ). More well-designed prospective studies with larger samples of those with a history of ankle sprains are needed to confirm these findings.

The optimal dose-response ratio to achieve the prophylactic effects of balance training is not known. The dosage of balance training needed to achieve preventive effects in healthy participants may be greater than that needed in those with previous ankle injuries. Because the risk of recurrent sprain is higher in those with a history of ankle sprains, prophylactic effects may be achieved with a lower volume of balance training. In contrast, the risk of ankle sprain among those without a history of sprain may be considered relatively low and, thus, greater physiologic changes may be needed in response to balance training to achieve a reduction in injury risk. Based on the balance training protocols in the studies reviewed,<sup>15–17</sup> exercises performed on an ankle disk at least 3 times per week throughout a competitive season appeared to provide prophylactic effects in athletes with a history of ankle sprain. At this time, the dosage of balance training necessary to achieve ankle injury prevention effects in athletes without a history of ankle sprains is unknown.

Although only 3 studies were included in this analysis, the samples were a fairly heterogeneous representation of male and female participants representing high school,<sup>16</sup> community-based,<sup>17</sup> and elite athletes.<sup>15</sup> From a clinical perspective, balance and coordination training is clearly an effective intervention to reduce the incidence and recurrence of ankle sprains for up to 2 years. Additionally, the longer these programs are implemented, the greater the preventive effect.<sup>15</sup> Balance and coordination may also have preventive benefits for other lower extremity injuries, such as anterior cruciate ligament tears.<sup>26</sup> Based on the evidence presented above, we recommend the use of balance and coordination training to prevent ankle sprains, especially in those with a history of ankle sprains.

## Can Balance and Coordination Training Improve Treatment Outcomes Associated With Acute Ankle Sprains?

Consistent evidence shows that balance and coordination training improved treatment outcomes associated with acute ankle sprains. Wester et al<sup>20</sup> and Holme et al<sup>19</sup> demonstrated a 54% to 76% reduction in the risk of recurrent ankle sprains after balance and coordination training for the treatment of an acute ankle sprain. From the NNT perspective, 5 patients with acute ankle sprains would need to be treated with balance and coordination training in order to prevent 1 recurrent sprain.

The length of follow-up for these 2 studies<sup>19,20</sup> was 8 to 12 months after injury. Verhagen et al<sup>17</sup> demonstrated that the risk of recurrent ankle sprain was substantially increased within the first 12 months after an ankle sprain. Additionally, the risk of a recurrent ankle sprain more than 12 months after the most recent ankle sprain was similar to the risk of sprain for athletes who had never incurred a previous sprain.<sup>17</sup> These findings indicate the importance of preventing recurrent sprains within the year immediately after initial ankle sprain.

Comprehensive initial treatment and prevention of recurrent ankle sprains have important effects on the quality of life of individuals who have suffered ankle sprains. Although ankle sprains are often considered to be rather innocuous injuries, patients commonly report continuing symptoms,<sup>27</sup> diminished physical activity levels,<sup>28</sup> and lower quality of life<sup>29</sup> for more than a year after ankle sprain. Additionally, mounting evidence suggests an association between severe and recurrent ankle sprains and the development of ankle osteoarthritis.<sup>30–32</sup> By reducing the recurrence of injury and preventing the development of CAI, patients may be more physically active and prevent the complications of significant lifestyle change due to previous injury.

Supervised rehabilitation<sup>19</sup> appeared to confer a greater ability to prevent recurrent ankle sprains than did a home balance program.<sup>20</sup> Similar to the prophylactic balance training programs discussed earlier, the optimal dosage of balance training to achieve beneficial effects in those recovering from acute ankle sprains is unclear. Holme et al<sup>19</sup> were able to achieve preventive effects with supervised balance training performed just twice weekly, whereas Wester et al<sup>20</sup> achieved preventive effects with 15 minutes of daily home balance training. Further research is needed to identify the optimal dosage of balance training in patients recovering from acute ankle sprains.

Although the risk of reinjury was clearly reduced, concomitant improvements were not seen in instrumented measures of postural control in patients performing balance training after acute ankle sprains. The point measures of effect sizes for all comparisons suggest an improvement in postural control after balance training; however, the CIs around the majority of these measures crossed zero. This finding may be due to the instrumented measures used, which may lack the sensitivity to detect improvements in postural control after balance and coordination training.<sup>19</sup> Also, Goldie et al<sup>18</sup> tested participants who had suffered acute ankle sprains within the past 2 years, whereas the other groups<sup>19,20</sup> had patients begin balance training as soon as possible after suffering an acute ankle sprain. The postural control deficits in Goldie et al's<sup>18</sup> participants may not have

been as apparent as during the acute stages of their injuries. This factor complicates the interpretation of the results, because these individuals may not have had measurable postural control deficits from the start of the trial. Additionally, Goldie et al's<sup>18</sup> participants did not all receive similar doses of balance training (range, 2 to 140 training sessions). It is also possible that detectable improvements may not have occurred in instrumented static postural control measures in response to balance training. Perhaps more challenging postural control tests, such as those involving dynamic balance tasks, would be more sensitive to detecting such changes. The reduction in the risk of reinjury may arise from the interaction of factors not directly associated with changes in traditional force plate-based measures of postural control.

The included studies provided a fair representation of the sexes and the severity of ankle sprain.<sup>18–20</sup> Future research is needed to identify the potential factors related to the reduction in risk of reinjury in those who have undergone balance and coordination training after suffering acute ankle sprains. Clinically, it is apparent that 6 to 8 weeks of balance and coordination training reduces the risk of recurrent ankle sprains. However, the optimal length, volume, and intensity of this type of training have yet to be determined. More high-quality randomized controlled trials with large sample sizes and varied program lengths, volumes, and intensities are needed.

### **Can Balance and Coordination Training Improve Treatment Outcomes Associated With Chronic Ankle Instability?**

Based on the findings of our systematic review, it is unclear whether balance and coordination training among individuals with CAI improved the treatment outcomes of preventing recurrent ankle sprains and improving measures of instrumented postural control during single-limb stance. We identified no studies that provided sufficient data for the calculation of RRR or NNT for preventing recurrent ankle sprains in those with CAI. Eils and Rosenbaum<sup>22</sup> noted a 60% decrease in self-reported episodes of ankle inversion episodes after their balance training intervention program; however, they did not report the actual number of recurrent sprains in the training and control groups. The need for well-designed randomized controlled clinical trials that examine the improvements in treatment outcomes and evaluate the risk of reinjury in those with CAI is obvious.

Whether measurable improvements in postural control existed after balance and coordination training in those with CAI is also unclear. Although the point estimates of effect sizes tended to show improvements in postural control measures associated with the balance training groups, the CIs tended to be wide and cross zero, thus providing uncertainty to the actual effect of the balance training programs. As stated in our companion review paper,<sup>33</sup> postural control deficits thought to be associated with CAI have not been consistently detected with the use of these instrumented postural control measures. Therefore, it is not surprising that these instrumented measures may also lack the sensitivity to detect improvements from balance and coordination training in those with CAI. In our companion paper,<sup>33</sup> we discussed a nonlinear approach to evaluating

postural control that assesses intrinsic components of center of pressure. Time boundary<sup>34,35</sup> has shown promise in detecting postural control deficits related to CAI when traditional measures did not. Perhaps novel nonlinear measures, such as time to boundary and approximate entropy,<sup>36</sup> are sensitive enough to detect improvements in postural control after balance training in those with CAI. Further research is certainly warranted in this area.

Another possibility is that the nature of the task of quiet standing in single-limb stance may not provide adequate challenge to produce detectable changes related to the causes of CAI. More challenging dynamic postural control tasks, such as the Star Excursion Balance Test, detect functional performance deficits associated with rehabilitation, including balance and coordination training, in those with CAI.<sup>37</sup> We, therefore, do not recommend the use of traditional instrumented postural control measures as a treatment outcome for those with CAI but instead recommend a more challenging task such as the Star Excursion Balance Test.

As discussed in our companion paper,<sup>33</sup> the lack of consistency in the inclusion and exclusion criteria for CAI across the different studies is troubling. It is not clear that groups across all studies had the same level of ankle dysfunction, thus confounding the interpretation of results. Additionally, the dosage of balance training varied across studies, again making concrete recommendations for clinical practice difficult to provide.

Although evidence is lacking to demonstrate the effectiveness of balance training in reducing recurrent ankle sprains and improving instrumented postural control measures in patients with CAI, some emerging evidence indicates improvements in self-reported function associated with balance training among individuals with CAI.<sup>24,38</sup> This finding provides some promise for the efficacy of this treatment; however, due to a lack of available empirical evidence at this time, whether balance and coordination training improve the treatment outcomes associated with CAI is unclear. Our conclusion conforms with that of a recent Cochrane review,<sup>39</sup> in which evidence related to common treatments associated with CAI was examined.

### **CONCLUSIONS**

Prophylactic balance and coordination training substantially reduced the risk of ankle sprains in athletes, with a greater effect seen in those with a history of sprain. Completing at least 6 weeks of balance and coordination training during recovery from an acute ankle sprain substantially reduced the risk of recurrent ankle sprain for up to 1 year; however, improvements in instrumented measures of postural control associated with this training were not consistently measured. Evidence is lacking to assess the reduction in the risk of recurrent sprains, inconclusive to demonstrate improved instrumented postural control measures, and limited, albeit promising, to show improvements in self-reported function in those with CAI who complete balance and coordination training.

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