Functional Rehabilitation Interventions for Chronic Ankle Instability: A Systematic Review

Kathryn A. Webster and Phillip A. Gribble

Context: Functional rehabilitation is often employed for ankle instability, but there is little evidence to support its efficacy, especially in those with chronic ankle instability (CAI). Objective: To review studies using both functional rehabilitation interventions and functional measurements to establish the effectiveness of functional rehabilitation for both postural control and self-reported outcomes in those with CAI. Evidence Acquisition: The databases of Medline, SPORTDiscus, and PubMed were searched between the years 1988 and 2008. Inclusion criteria required articles to have used a clinical research trial involving at least 1 functional rehabilitation intervention, have at least 1 outcome measure of function and/or functional performance, and to have used at least 1 group of subjects who reported either repeated lateral ankle sprains or episodes of “giving way.” The term functional was operationally defined as dynamic, closed-kinetic-chain activity other than quiet standing. Evidence Synthesis: Six articles met the inclusion criteria. The articles reviewed used multiple functional means for assessment and training, with a wobble board or similar device being the most common. Despite effect sizes being inconsistent for measures of dynamic postural control, all interventions resulted in improvements. Significant improvements and strong effect sizes were demonstrated for self-reported outcomes. Conclusions: The reviewed studies using functional rehabilitation interventions and functional assessment tools were associated with improved ankle stability for both postural control and self-reported function, but more studies may be needed with more consistent effect sizes and confidence intervals to make a definitive conclusion.

Keywords: postural control, closed kinetic chain, therapeutic exercise, wobble board

Ankle sprains are among the most common injuries seen in athletic participation, with reinjury rate for athletes with lateral ankle sprains as high as 70% to 80%, leading to the development of chronic ankle instability (CAI). Clinicians are faced with many factors that need to be addressed after lateral ankle sprains, including muscle weakness, postural-control deficits, decreased range of motion, and the frequent occurrence of reinjury. With the goal of returning patients to

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high levels of function in a limited time frame, clinicians are challenged to find approaches that will improve ankle stability and prevent reinjury.

**CAI**

CAI is characterized by residual lateral instability leading to repetitive ankle sprains and is a result of functional ankle instability, mechanical ankle instability, or a combination of the 2. Deficits in postural control and strength are involved after injury, as well as structural laxity of the joint. Recently, aspects of both functional and mechanical ankle instability have been demonstrated to be significantly different in those with CAI compared with matched healthy ankles. There are multiple proposed risk factors for ankle-ligament injury, with evidence for a multifactorial pathology.

A recent trend in injury rehabilitation is to move toward a more functionally based approach, including more emphasis on functional movement than quiet standing and more closed- than open-kinetic-chain positioning. For the purpose of this article, the term *functional* will be operationally defined as dynamic, closed-kinetic-chain activity other than quiet standing. The effectiveness of this type of intervention needs to be evaluated with an evidence-based approach.

Before investigating rehabilitation protocols for those with CAI, it is important to determine if there are differences in functional performance for those with CAI compared with healthy ankles. When investigating functional tasks, multiple studies have demonstrated significant differences in CAI ankles compared with healthy ankles. Several authors have reported deficits in performance and dynamic postural control during hopping and jumping tasks. Other authors report consistent deficits in dynamic postural control measured with the Star Excursion Balance Test in those with CAI. Although some studies have reported no differences in subjects with CAI while performing tasks such as shuttle run, agility hopping, and triple crossover hopping, it is important to note that these studies used the criterion of only 1 ankle sprain to define CAI.

If clinicians do not address these deficits in dynamic postural control and performance during functional tasks in those with CAI, we may continue to see acute ankle sprains become chronic. With a functionally based approach to treating those with CAI becoming more popular, it is important to review the current research to help clinicians determine whether emphasizing functional rehabilitation will help improve deficits of dynamic postural control and functional performance found in those with CAI in an effort to prevent future ankle injury.

**Objective**

The purpose of this article is to review studies that have used both functional rehabilitation interventions and functional assessment tools to establish the effectiveness of functional rehabilitation for those with CAI. With this objective in mind and the types of studies found through the search criteria, 2 specific questions will be addressed: (1) Does functional rehabilitation improve dynamic postural control in those with CAI? and (2) Does functional rehabilitation improve self-reported outcomes in those with CAI? By examining studies that meet the inclusion criterion of...
functionally based assessments, a better appreciation of the outcomes of functionally based rehabilitation programs can be established through the categories of dynamic postural control and self-reported outcomes. It is our hope that through this review, clinicians may be able to discern whether using this type of intervention is helpful in the rehabilitation of patients with repeated ankle sprains in their return to activity.

**Evidence Acquisition**

Six randomized control trials or cohort studies were reviewed that involved a functional rehabilitation intervention for those with CAI. Four of the 6 studies used measures of dynamic postural control whose outcomes contribute to answering the first question posed. Five of the 6 studies used some form of self-reported outcome whose results lend to answering the second question posed.

**Study Search and Selection**

The databases of Medline, SPORTDiscus, and PubMed were searched in December of 2008 for clinical studies from 1988 to 2008. Details of the search limits and results can be found in Table 1. Searches included the following key words either alone or in combination: ankle, ankle instability, recurrent sprains, functional, rehabilitation, wobble board, ankle disk, agility, proprioception, and plyometric. The terms wobble board and ankle disk were specifically used because of the commonality of these tools in functional ankle rehabilitation. We felt that these combinations of terms would allow the broadest and most appropriate collection of articles to be identified. After the terms were searched and limits applied, the combined total number of articles found from these database searches, not accounting for repeated articles, was 3952. The following inclusion criteria were then applied to the search:

- The clinical trial involved at least 1 functional rehabilitation intervention (as defined in the introduction section of this article).
- Measurements used in the study had at least 1 outcome measure of function or functional performance.
- The study used at least 1 group of subjects with a history of previous ankle injury who reported either repeated lateral ankle sprains or episodes of “giving way.”

**Assessment of Methodological Quality**

The articles were reviewed, and if an article was not already rated by the Centre for Evidence-Based Physiotherapy (PEDro), we used the PEDro scoring system to rate it. There were no discrepancies between the 2 authors’ scores. The score for the clinical trials is determined by using a checklist created by the Physiotherapy Evidence Database. The 2 categories of criteria by which trials are scored are internal validity and whether a trial contains sufficient statistical information to make it interpretable. The results of this scoring can be found in Table 2.
Table 1  Article Search Results

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Table 1 (continued)

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Table 2  Article Content Summary

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<tr>
<th>Authors</th>
<th>Subject population</th>
<th>Intervention</th>
<th>Form of measurement</th>
<th>Results</th>
<th>Effect sizes</th>
<th>Oxford</th>
<th>PEDro</th>
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<tr>
<td>Rozzi et al28</td>
<td>Healthy and CAI. 2 ankle sprains and giving way.</td>
<td>Balance training on Biodex 3×/wk, 4 wk.</td>
<td>Postural-sway Biodex Balance System for static balance at levels 2 and 6.</td>
<td>Both impaired and unimpaired subjects experienced improvement in the trained leg. Improved score on AJFAT.</td>
<td>Exercise group level 2: 1.18, level 6: 0.63. AJFAT: –2.4.</td>
<td>2b–</td>
<td>4</td>
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<td>Stasinopoulos31</td>
<td>Healthy and CAI. Suffered ankle sprains to hold out for at least 3 d.</td>
<td>Technical training in jump landing, balance board, stirrup braces. Entire volleyball season.</td>
<td>Number of ankle sprains recorded in the following season.</td>
<td>All 3 interventions were effective in reducing the number of ankle sprains. Of the athletes with 3 or more sprains, technical training slightly more effective than the other interventions, orthosis not effective for this group.</td>
<td>RR: proprioceptive group, 0.13; strength group, 0.5; orthosis group, 0.25.</td>
<td>2b–</td>
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<td>Hale et al25</td>
<td>Healthy and CAI. History of unilateral ankle sprain with pain or limping for &gt;1 d, chronic weakness, ankle giving way in last 6 mo.</td>
<td>Combination of stretching, Thera-Band strengthening in multiple directions, neuromuscular control, jumping and running drills 3.5×/week for 4 weeks.</td>
<td>COPV, SEBT, FADI, FADI-Sport.</td>
<td>Rehab group improved in measurements of SEBT, FADI, and FADI-Sport.</td>
<td>SEBT: postero-medial reach: 0.57, postero-lateral reach: 0.39, lateral reach: 0.35. FADI: 0.80. FADI-Sport: 0.92.</td>
<td>1 b</td>
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<th>Authors</th>
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<th>Results</th>
<th>Effect sizes</th>
<th>Oxford</th>
<th>PEDro</th>
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</thead>
<tbody>
<tr>
<td>Mohammadi&lt;sup&gt;30&lt;/sup&gt;</td>
<td>All CAI. History of unilateral ankle sprain causing a player to miss practice or match.</td>
<td>Group 1: ankle-disk training 30 min/d. Group 2: eversion strengthening with Thera-Band. Group 3: Air-Stirrup (Aircast Inc). Group 4: control.</td>
<td>Number of ankle sprains recorded in the following season.</td>
<td>Significant decrease in ankle sprains in ankle-disk group compared with control. No significant differences in the strengthening or brace groups compared with control.</td>
<td>RR: Technical training group, 0.31; proprioceptive group, 0.49.</td>
<td>1b</td>
<td>6</td>
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<td>Ross and Guskiewicz&lt;sup&gt;27&lt;/sup&gt;</td>
<td>Healthy and CAI. History of ankle sprain requiring immobilization, 2 subsequent ankle sprains, 2 episodes of giving way.</td>
<td>Single-leg stance balance on foam, circular motion on wobble board, resistance-band kicks in 4 directions 10 min/d, 5 d/wk, 6 wk.</td>
<td>APTTS and MLTTS at 2, 4, and 6 wk.</td>
<td>Coordination training improved anteroposterior dynamic stability after 2 wk and mediolateral dynamic stability after 4 wk of training for those with CAI.</td>
<td>APTTS, –0.40; MLTTS, 0.30.</td>
<td>2b–</td>
<td>3</td>
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<tr>
<td>McKeon et al&lt;sup&gt;26&lt;/sup&gt;</td>
<td>All CAI. History of &gt;1 ankle sprain with subsequent giving way episodes. ≤90% on FADI and FADI-Sport.</td>
<td>Progressive balance training including multidirectional hop landing and single-leg-stance progressions. 20 min/d, 3 d/wk, 4 wk.</td>
<td>COP excursion measures, time to boundary, SEBT, FADI, FADI-Sport.</td>
<td>Significant improvements in FADI and FADI-Sport, improved reach distances in SEBT.</td>
<td>SEBT posteromedial reach 0.64, posterolateral reach 0.67. FADI: 0.98. FADI-Sport: 1.25.</td>
<td>1b</td>
<td>5</td>
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</table>

CAI, chronic ankle instability; AJFAT, Ankle Joint and Foot Assessment Tool; RR, risk ratio; COPV, center-of-pressure velocity; SEBT, Star Excursion Balance Test; FADI, Foot and Ankle Disability Instrument; APTTS, anteroposterior time to stabilization; MLTTS, mediolateral time to stabilization; COP, center of pressure.
Data Extraction

Using the inclusion criteria on titles alone, 3851 articles were eliminated, leaving 101 articles. After we applied the inclusion criteria to the abstracts, 70 more articles were eliminated, leaving 31 articles. After we read the 31 remaining articles in their entirety, 25 more were eliminated because they did not fit the inclusion criteria. This left 6 studies included in this review that met the inclusion criteria and addressed dynamic postural control and self-reported function. Table 1 details how many articles were found in each search engine, results for each search-word combination, and the number of articles eliminated after we read the title, abstract, and complete manuscript. A summary of the findings from these studies may be found in Table 2, including authors, subject populations, rehabilitation interventions, duration and intensity of rehabilitation interventions, forms of measurement, and results.

Statistical Analysis

For 4 of the 6 studies included,\textsuperscript{25–28} effect sizes were not presented by the authors of the articles, and we calculated them using the formula presented by Cohen.\textsuperscript{29} The effect-size scale used was .2 = small, .5 = moderate, and .8 = large.\textsuperscript{29} Ninety-five-percent confidence intervals around the effect sizes were also calculated for these studies, and the results can be found in Figures 1 and 2. Two of the studies\textsuperscript{30,31} did

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Effect sizes and 95\% confidence intervals for studies that provided means and SDs for dynamic postural-control measures. SEBT, Star Excursion Balance Test; PL, posterolateral reach; PM, posteromedial reach; Ant, anterior; MLTTS, mediolateral time to stabilization; APTTS, anteroposterior time to stabilization; Lat, lateral reach.}
\end{figure}
not report standard deviations, which prevented us from calculating effect sizes. These studies tracked the number of subsequent sprains after the rehabilitation protocol, so relative risk calculations were made.

**Levels of Evidence and Strength of Recommendation**

All articles were reviewed using the Oxford Centre for Evidence-based Medicine levels of evidence. Grades of recommendation presented by the Oxford Centre for Evidence-based Medicine were also applied. These results can be found in Table 2.

**Evidence Synthesis**

To determine whether emphasizing functional rehabilitation will help improve deficits of dynamic postural control and self-reported function in those with CAI, the results were summarized across the articles into a section for the interventions, as well as for the outcome tools.

**Methodological Quality and Study Characteristics**

As previously mentioned, the 6 studies were rated either by us or by the PEDro Web site. The highest PEDro rating was a 6, with the average PEDro score being 4 out of a possible 10. Individual scores are listed in Table 2.

**Data Synthesis**

Of the 6 studies that met the inclusion criteria, 4 studies implemented the use of a wobble board or similar tool either alone or in combination with other rehabilitation tools. Two of the studies incorporated the use of jump-landing training for dynamic postural control as an intervention for rehabilitation. None of the studies reported subject attrition through the rehabilitation intervention. Four of the 6 studies reported intensity and duration of the rehabilitation protocols,

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**Figure 2** — Effect sizes and 95% confidence intervals for studies that provided means and SDs for self-reported functional measures. FADI, Foot and Ankle Disability Instrument; AJFAT, Ankle Joint and Foot Assessment Tool.
which can be found in Table 2 in the Intervention column. One of the remaining 2 studies reported the intensity but no duration. The final study reported an ambiguous time frame of “1 volleyball season.”

Assessment Tools

Dynamic Postural Control. There was a diversity of measurement techniques of ankle stability in the 6 studies. Four studies used the Star Excursion Balance Test, Biodex Stability System, or time to stabilization. Effect sizes were calculated for these studies, as well as confidence intervals around the effect sizes, which can be found in Figure 1. The range of effect sizes for the measurements performed in the studies was small to large (0.38–1.18), with a moderate average of .64. Of the 10 measures of outcomes in these 4 studies, the confidence interval crossed zero 3 times.

Self-Reported Function. Two of the studies not yet mentioned followed the athletes through a sport season subsequent to the rehabilitation protocol and documented the number of recurrent ankle sprains during competitive activity. Both studies did have significant decreases in the number of ankle reinjuries after rehabilitation, but neither provided means and SDs for their results, preventing the calculation of effect sizes. Relative risk (RR) was reported in 1 of the studies as 0.13 (95% CI, 0.003–0.93) for the proprioceptive training group and 0.5 (95% CI, 0.11–1.87) for the strength-training group compared with the control group with 3.33 (95% CI, 0.12–1.91). The final study did not include a control group as part of its design but did use an ankle-brace group to compare with a technical landing-training group and a proprioceptive-training group. We calculated RR using the braced group as a control group and found that the technical training group’s RR was 0.31 and the proprioceptive group’s was 0.18. Although we understand that this is not the ideal manner to calculate RR, we used this calculation for the sake of comparison with the other studies. This article did not provide standard deviations, so we could not calculate confidence intervals or effect sizes for this statistic.

Self-reported level of ankle function was employed by 3 of the 6 studies by use of a questionnaire. Data from the Ankle Joint Functional Assessment Tool (AJFAT) was reported by 1 study, and 2 studies used the Foot and Ankle Disability Index (FADI) and FADI-Sport. The means and SDs for the outcomes of these tools were used to calculate effect sizes. These were high for all 3 studies and ranged from 0.77 to 2.66 with an average of 1.32. Two confidence intervals crossed 0. All 3 studies reported significant improvements in ankle function recorded through the questionnaires.

Levels of Evidence and Strength of Recommendation

Implementing the Oxford Centre for Evidence-Based Medicine levels of evidence, the studies reviewed ranged from a 1b to 2b. Although some of the studies had moderate to large confidence intervals, the design of these cohorts and randomized control trials was strong. We graded the strength of recommendation as a b.

The PEDro scoring for most of these articles was low, an average of 4 out of a possible 10. Although this may indicate below-average evidence-based research, the low score may be attributable to the nature of most of the studies performed.
Although many of the PEDro criteria are useful in studies involving interventions such as modalities or medication, where sham treatments and blinding are feasible, it is difficult in clinical research trials involving rehabilitation interventions to account for these practices, resulting in missing multiple potential points on the PEDro scale. The studies reviewed would have no ability to conceal many of the criteria necessary for attaining points on the PEDro scale. For example, group allocation is challenging to conceal when it is obvious to a subject whether he or she is in the exercise or control group. It is also difficult to blind the therapists when they can obviously see if a subject is performing the exercises or not. Other criteria required for points on the PEDro scale would have compromised the design of these studies. For instance, when studies compare a healthy control group with a CAI group, the study loses a point for groups not being similar at baseline. Two other points on the PEDro scale, intention to treat and measures attained from 85% of the group, are areas that are often understood or implied, but PEDro requires these criteria to be clearly stated in the study to get points in these areas. This may help explain why these clinical research trials did not score well. For clinical research trials involving rehabilitation, measures of variability such as effect size, as well as RR, may be better indicators of the clinical significance of the study.

Discussion

Although reviews of the ankle-rehabilitation literature have been produced recently on general ankle rehabilitation\textsuperscript{33,34} and specific to dynamic postural control,\textsuperscript{35} the current review considered studies using both functional interventions and functional measurements, specifically for the pathology of CAI. These criteria were selected because ankle injury and reinjury occur during functional situations, and clinicians may be interested in learning whether current functional rehabilitation interventions are effective for improving functional measures and preventing further injury. Therefore, when reviewing the current research on this topic, it was important to find studies that implemented both functional measures and functional assessment tools. A unique aspect of this review was that all included studies used subjects with a history of ankle injury who were exposed to functional rehabilitation interventions such as wobble board, agility testing, multidirectional hopping, or jump-landing education, as well as using functional assessment tools to measure dynamic postural control or self-reported stability of decreased reinjury or giving way.

All the reviewed studies showed some form of improvement in outcomes from functional interventions; however, the measured outcomes of these studies were varied and difficult to compare directly. All studies showed improvements in outcome measures for those with CAI, and where RR ratios were calculated, all results were less than 1, indicating a decreased risk of ankle injury after functional rehabilitation. Four\textsuperscript{25–28} of the 6 articles provided means and SDs, which enabled us to calculate effect sizes and 95% confidence intervals around the effect sizes (Figures 1 and 2). Effect sizes ranged from small to large, with some of the 95% confidence intervals crossing 0. These results make an overall conclusion regarding efficacy of these rehabilitation programs difficult. For the purpose of greater clarification the results from these studies can be separated into 2 categories based on the questions outlined earlier: (1) Does functional rehabilitation improve dynamic...
postural control in those with CAI? and (2) Does functional rehabilitation improve self-reported outcomes in those with CAI?

**Does Functional Rehabilitation Improve Dynamic Postural Control in Those With CAI?**

Effect sizes are designed to reflect clinical relevance of the results of a study. When considering confidence intervals around an effect size, it is important to note not only the size of the confidence interval but also whether it crosses 0. Ninety-five-percent confidence intervals around an effect size help to assure that the effect size is repeatable within a range 95% of the time. A 95% confidence interval about an effect size that does not cross 0 implies that 95% of the time, replication of the study would not yield an effect size of 0, or no effect. When it does cross 0, one should consider whether a true difference was actually detected and how reliable the effect size would be if the study were repeated. Therefore, studies whose results have large effect sizes and small confidence intervals that do not cross 0 have the strongest clinical significance.

In terms of the effect sizes and confidence intervals for dynamic postural control, Rozzi et al.\(^28\) had large effect sizes, but both confidence intervals were wide and crossed 0. Ross et al.\(^27\) had large to moderate effect sizes, with the confidence intervals being moderate and 1 crossing 0. McKeon et al.\(^26\) had moderate effect sizes for dynamic postural control, but all 3 confidence intervals for the measures observed for this study were small and did not cross 0. Hale et al.\(^25\) demonstrated small to moderate effect sizes but had small confidence intervals that did not cross 0. Although all these studies did demonstrate significant improvements in dynamic postural control, varying effect sizes and confidence intervals make it difficult to determine a conclusive answer regarding the rehabilitation protocols they used.

There were several methods of assessing dynamic postural control and stability in the articles included in this review. Although this article focuses on the efficacy of the functional intervention, it is important to establish whether the measurement tools implemented in the studies were appropriate for measuring improvements in ankle stability. The Biodex Stability System used by Rozzi et al.,\(^28\) the Star Excursion Balance Test used by MeKeon et al.\(^26\) and Hale et al.,\(^25\) and the time-to-stabilization technique implemented by Ross and Guskiewicz\(^27\) have all been previously established as reliable assessments of postural control.\(^36^-^42\) This helps add strength to the conclusions made in these studies that dynamic postural control did improve in subjects with CAI after the functional rehabilitation intervention, but one must also consider the fact that the effect sizes and confidence intervals varied among the results, making a clear conclusion difficult.

**Does Functional Rehabilitation Improve Self-Reported Outcomes in Those With CAI?**

Three of the studies\(^25^,\)\(^26^,\)\(^28\) reviewed used subjective questioning of the subjects regarding ankle functional ability, which included the FADI, FADI-Sport, and the AJFAT. All 3 showed significant improvement and demonstrated large effect sizes. Ninety-five-percent confidence intervals for Hale et al.,\(^25\) who implemented the FADI
and FADI-Sport, were small and did not cross 0. Rozzi et al\textsuperscript{28} reported a strong effect size for the AJFAT, but larger confidence intervals, whereas McKeon et al\textsuperscript{26} also had a very large effect sizes, but both the FADI and FADI-Sport demonstrated large confidence intervals that crossed 0.

The FADI and FADI-Sport\textsuperscript{40} used by McKeon et al\textsuperscript{26} and Hale et al,\textsuperscript{25} as well as the AJFAT\textsuperscript{42} implemented by Rozzi\textsuperscript{28} have been established as reliable tools for identifying ankle pathology and determining effective outcomes for patients with ankle instability. This would indicate that because the tools are reliable and the patients reported significant improvements in functional activity, as well as activities of daily living, the interventions were successful.

The 2 studies\textsuperscript{30,31} that used number of subsequent sprains after returning to activity both presented RRs <1, implying a reduced risk of reinjury after completing the rehabilitation protocol. This also contributes to the argument that functional rehabilitation improves self-reported outcomes in those with CAI.

Overall, the multiple assessment tools for self-reported function that were implemented in the studies reviewed all demonstrated improvements in ankle stability. Despite 1 study whose confidence interval crossed 0, all other findings suggest that functional rehabilitation does, in fact, improve self-reported outcomes for those with CAI. This is a key finding because, practically, the goal is to stop the cycle of ankle reinjury, which these studies are reporting is happening with functional rehabilitation. Therefore, in our opinion clinicians can implement dynamic, closed-chain rehabilitation exercises for 4 to 6 weeks, 3 or 4 times a week with confidence, knowing that patients who have completed these protocols have significant improvements in self-reported function.

There are a few considerations to be made with this conclusion. Two of the reviewed studies\textsuperscript{30,31} that used rate of recurrence as an outcome measure had some major limitations to consider. In the Stasinapolous\textsuperscript{31} study, the inclusion of a control group would have increased validity and helped substantiate that decreases in ankle reinjury were more likely a result of the training. Although this study reported significant reductions in ankle-sprain recurrence, the investigators did not report means and SDs but only reported percentages of recurrence. In addition, the tracking of injuries was not well documented and may have been more accurate if collected more often than at the end of the year. In the Mohammadi\textsuperscript{30} article, there was little to no explanation of the intervention protocols themselves (ie, how they were advanced, frequency of the rehabilitation, duration of the rehabilitation), making repeatability difficult for clinicians. In addition, there did not appear to be any supervision of the rehabilitation protocols or orthosis use, and it was not stated how the injury occurrences were documented. This may have influenced data collection and the conclusions drawn from the data.

**Interventions**

As to be expected, there was a large amount of variability in the rehabilitation protocols used across the included studies, including the length of time and exercises used. Although some provided more details than others, most of the studies reported clearly the length of intervention time, the included exercises, and the manner by which subjects progressed through the rehabilitation protocol. The only study that did not provide adequate detail about the intervention protocol was that
of Mohammadi,\textsuperscript{30} who gave no indication of the duration, frequency, and criteria for advancement of the rehabilitation. Although both Stasinopoulos\textsuperscript{31} and Mohammadi\textsuperscript{30} did report favorable outcomes in reducing additional ankle sprains, with RRs $<1$, these issues may make the application and replication of the data difficult.

Neither Mohammadi\textsuperscript{30} nor Stasinopoulos\textsuperscript{31} reported a length of time the exercises were performed, but all other studies were either 4 weeks\textsuperscript{25,26,28} or 6 weeks\textsuperscript{27} in length, which is common for intervention programs. The frequency per week varied from 3 to 5 times, which is also relatively common for a rehabilitation protocol. These rehabilitation practices do not seem to differ from most current rehabilitation recommendations or clinical practices, and because 1 study did not stand out from the others as having all components of strong efficacy (high effect sizes and small confidence intervals that did not cross 0), it appears that a 4- to 6-week program performed 3 to 5 times a week can improve both dynamic measures of postural control and self-reported outcomes.

One note of continuity for intervention was that five\textsuperscript{26–28,30,31} of the reviewed studies used some form of training on an instrument similar to a wobble board. Wobble boards have often been used as a staple in rehabilitation protocols for acute and subacute lateral ankle sprains. Using subjects with acute rather than chronic ankle sprains, Wester et al\textsuperscript{43} reported that a wobble-board training program proved to be an effective means of training and preventing reinjury to the ankle after the initial incident. Although Wester et al\textsuperscript{43} did not fit our inclusion criteria of subjects with CAI, their findings are consistent with the studies in our systematic review, indicating that wobble boards are effective in the rehabilitation of multiple stages of ankle instability.

**Recommendations for Future Research**

It is understood that definitions of CAI can differ. Although the actual number of ankle sprains required for inclusion was not consistent across all reviewed studies, the studies included in this systematic review all used subjects who reported repeated episodes of giving way. A recent comparison of 25 published articles on subjects with CAI reported very low agreement between the inclusion criteria used in this body of work, suggesting a high level of inconsistency in the validity of research on CAI and the need for a more consistent set of inclusion criteria to describe this pathology.\textsuperscript{44} In the articles we reviewed, the number of exact ankle sprains or the average number of ankle sprains of participants was not consistently reported, which may lead to different outcomes. We recommend additional dialogue among researchers and clinicians to establish a set of criteria for this pathology.

In addition, it would be helpful for studies to include effect sizes and confidence intervals, as well as relative RRs, to better describe the practical efficacy of protocols and to make more conclusive recommendations. These practices will help clinicians implement changes in practice to improve patient outcomes. Along the same lines, a clear explanation of rehabilitation protocols would be helpful to readers, not necessarily for a cookbook type of approach to treating CAI, but for exchange of ideas to apply to cases presented to clinicians.

More research, in general, on functional ankle rehabilitation is recommended. The number of studies compared here, 6, may be too small to make a conclusive evidence-based decision. There is no specific number of studies required to make an
irrefutable decision about practices performed in our profession. We must critically consider the evidence presented and make decisions as clinicians as to whether we should implement changes in our own practice.

Another recommendation is for more prospective studies to see if interventions truly accomplish the goal of preventing further injury for those who deal with recurrent injury during activity or daily life. Although CAI is a multifactorial condition, the purpose of research is to better understand how it becomes chronic and to limit future injury, and prospective studies help give a better picture of how well we are accomplishing this goal.

Conclusions

Despite varying effect sizes and confidence intervals, the studies covered by this review provide support for the efficacy of functional, closed-chain, dynamic interventions for patients with CAI, especially the use of unstable surfaces such as the wobble board. All studies showed improvements in both dynamic postural control and self-reported function in those with CAI. Many clinicians currently implement dynamic, closed-kinetic-chain rehabilitation exercises for patients with repeated ankle sprains in hope of returning patients to functional activities and preventing future incidents of giving way. The findings of this review suggest that both dynamic postural control and self-reported measures improve from this type of intervention. However, it is clear that more high-quality research is needed in this area to ensure the efficacy of functional dynamic rehabilitation for those with CAI.

Practice Recommendations

- Functional rehabilitation shows improvements in measures of dynamic postural control and self-reported outcomes, which in some of the studies reviewed reduced the actual recurrence of injury.
- The use of wobble boards is implemented consistently across the studies in this review and their continued use in rehabilitation programs is supported by the literature.
- Functional rehabilitation programs in the reviewed studies consistently lasted 4 to 6 weeks, 3 to 5 times a week, and improved dynamic postural control and self-reported outcomes.

References


