

THE EFFECT OF PROPRIOCEPTIVE EXERCISES ON IMPROVING ANKLE STABILITY IN ATHLETES WITH CHRONIC ANKLE INSTABILITY

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Abstract

Chronic Ankle Instability (CAI) merupakan kondisi yang sering terjadi pada atlet dan dapat memengaruhi stabilitas serta fungsi pergelangan kaki. Salah satu pendekatan yang banyak digunakan untuk meningkatkan stabilitas ankle adalah proprioceptive exercise. Penelitian ini bertujuan untuk menganalisis efektivitas proprioceptive exercise terhadap peningkatan stabilitas ankle pada atlet dengan CAI. Penelitian ini menggunakan desain systematic review dan meta-analisis dengan sumber data sekunder yang diperoleh dari hasil penelitian terdahulu yang relevan. Artikel yang memenuhi kriteria inklusi kemudian diseleksi dan dianalisis secara kuantitatif untuk memperoleh estimasi ukuran efek. Sebanyak delapan artikel penelitian memenuhi kriteria dan digunakan sebagai sumber data meta-analisis. Hasil analisis menunjukkan bahwa proprioceptive exercise memberikan efek positif dan signifikan terhadap peningkatan stabilitas ankle pada atlet dengan CAI, dengan nilai standardized mean difference (SMD) sebesar 1,10 (95% CI: 0,45–1,75; $p = 0,00009$). Nilai tersebut menunjukkan efek yang besar terhadap peningkatan stabilitas ankle. Dengan demikian, proprioceptive exercise dapat menjadi salah satu intervensi yang efektif dalam meningkatkan stabilitas ankle pada atlet dengan CAI.

Keywords: *Proprioceptive Exercise, Stabilitas Ankle, Chronic Ankle Instability, Atlet, Meta-Analysis.*

Article History

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A. INTRODUCTION

The ankle is a vital part of the musculoskeletal system that plays a role in maintaining balance, postural control, and the ability to perform various functional and athletic activities. For athletes, the demands of high-intensity physical activity—including acceleration, deceleration, changes in direction, jumps, landings, and rotational movements—place significant stress on the lower extremities, particularly the ankle joint. These conditions make the ankle one of the body parts most prone to sports injuries (Romadhoni et al., 2022). Ankle injuries that are not treated optimally can lead to functional impairment and increase the risk of recurrent injuries, especially in athletes who continue to engage in high-intensity activities.

One condition that often arises after an ankle injury is Chronic Ankle Instability (CAI). CAI is characterized by recurrent episodes of the ankle “giving way,” a feeling of instability in the ankle, and sensorimotor dysfunction that may persist after a previous ankle injury. This condition is not only related to ligament weakness but may also involve impairments in neuromuscular control, balance, muscle strength, and sensorimotor function. In athletes, these issues have the potential to hinder athletic performance and increase the risk of recurrent injuries (Donovan et al., 2020; McCann et al., 2021). Therefore, improving ankle stability is a key aspect of the rehabilitation process and the prevention of recurrent injuries in athletes with CAI.

CAI can develop as a result of injury to the lateral ligament complex of the ankle, particularly during sudden inversion and plantar flexion. In addition to structural factors, the occurrence of instability is also influenced by functional factors such as balance disorders, decreased neuromuscular control, weakness of the muscles surrounding the joint, and proprioceptive disorders. Environmental factors, such as uneven playing surfaces and the use of inappropriate footwear, can also increase the demands on the

ankle's stabilization mechanisms (Cruz-Díaz et al., 2020; Wagemans et al., 2022). Therefore, the management of CAI must consider not only the restoration of the injured structures but also the restoration of sensorimotor function and the body's ability to maintain joint stability.

Proprioceptive impairment is a key aspect of CAI because proprioception plays a role in providing information about the position and movement of the limbs to the central nervous system. This information originates from various sensory receptors and is subsequently integrated to generate an appropriate motor response. A decline in proprioceptive ability can disrupt postural control and neuromuscular responses, thereby reducing the ability to maintain ankle stability. Therefore, exercises designed to improve proprioceptive function are a widely used approach in the rehabilitation and prevention of ankle injuries.

Proprioceptive exercise is a form of exercise designed to improve the body's ability to receive, integrate, and respond to sensory information regarding joint position and movement. These exercises may involve balance activities, postural control, positional changes, and various forms of sensorimotor exercises that stimulate the neuromuscular system. Increased sensory input through proprioceptive exercises is expected to improve motor responses, enhance neuromuscular control, and ultimately improve the functional stability of the ankle. Thus, proprioceptive exercises have the potential to serve as an intervention in the management of CAI in athletes.

A number of previous studies have evaluated the effectiveness of proprioceptive exercises on balance and ankle stability in individuals with CAI. However, the available research findings still show variation in subject characteristics, intervention type and duration, stability measurement instruments, and the magnitude of the intervention's effects. These differences mean that conclusions regarding the effectiveness of proprioceptive exercises have not yet provided a fully consistent quantitative picture, particularly in the population of athletes with CAI. Therefore, a synthesis of the available research findings is needed to obtain a more objective estimate of the intervention's effects.

Based on these issues, this study was conducted using a systematic review and meta-analysis approach to identify and synthesize research evidence regarding the effectiveness of proprioceptive exercises on ankle stability in athletes with CAI. A meta-analysis allows the results of several independent studies to be statistically combined to obtain an overall estimate of the effect size. The results of this study are expected to provide stronger scientific evidence regarding the effectiveness of proprioceptive exercises and serve as a basis for determining exercise strategies that can be used to improve ankle stability in athletes with CAI.

B. RESEARCH METHOD

Research Design

This study used a systematic review and meta-analysis to identify, evaluate, and quantitatively synthesize research findings on the effectiveness of proprioceptive exercises for ankle stability in athletes with Chronic Ankle Instability (CAI). The data used were secondary data obtained from primary studies published in scientific journals. The systematic review was conducted systematically through the stages of identification, screening, eligibility assessment, and inclusion of articles that met the study criteria.

A systematic review is a research method used to identify, critically evaluate, and synthesize the results of primary studies relevant to a specific research question. Meanwhile, a meta-analysis is a statistical technique used to combine the results of several independent studies to obtain an overall estimate of the effect size (Thomas &

Thomas, 2019; Mustafovic et al., 2020). Thus, the meta-analysis in this study was used to obtain a quantitative estimate of the effect of proprioceptive exercise on ankle stability in athletes with CAI.

Literature Search Strategy

A systematic literature search was conducted in several electronic databases, namely PubMed, Google Scholar, Web of Science (WoS), and ScienceDirect. The articles considered in this study were those published between 2014 and 2024. This time frame was selected to obtain relevant research evidence regarding the use of proprioceptive exercises in the management of CAI.

The search strategy was developed based on the main concepts of the study, which include the condition (Chronic Ankle Instability), the intervention (proprioceptive exercise), and the outcome (ankle stability). Keywords used in the search process included "proprioceptive exercise," "proprioceptive training," "Chronic Ankle Instability," "ankle instability," "ankle stability," and "athlete." The keywords were combined using the Boolean operators AND and OR to broaden or narrow the search results according to the study's needs.

An example of the search strategy used is:

> ("proprioceptive exercise" OR "proprioceptive training" OR "balance training") AND ("Chronic Ankle Instability" OR "ankle instability") AND (athlete OR athletes) AND ("ankle stability" OR "postural stability" OR balance)

The search was conducted by assessing the relevance of the titles, abstracts, and keywords to the research questions. Articles retrieved from all databases were then compiled and reviewed to identify duplicates before undergoing further screening.

Inclusion and Exclusion Criteria

Inclusion criteria were established to ensure that the articles analyzed possessed characteristics consistent with the study's objectives. Articles were included if they met the following criteria: (1) the study involved athletes or individuals actively engaged in sports; (2) the study subjects had chronic ankle instability or a history of ankle instability; (3) the study provided an intervention in the form of proprioceptive exercise, proprioceptive training, or exercises that clearly included a proprioceptive component; (4) the study included a control group or pre- and post-intervention data that allowed for the calculation of effect sizes; (5) the study reported outcomes related to stability, balance, postural control, or sensorimotor function of the ankle; (6) the article was a primary study; and (7) the article was published between 2014 and 2024 in Indonesian or English.

Articles were excluded if: (1) they did not address CAI or ankle instability; (2) the primary intervention was not a proprioceptive exercise; (3) the subjects did not constitute a population meeting the study criteria; (4) the article was a review, systematic review, meta-analysis, editorial, letter to the editor, or conference proceedings that did not provide the necessary quantitative data; (5) the article does not provide data that can be used to calculate effect sizes; or (6) the article is a duplicate of a study already found in another database.

Article Selection Procedure

The article selection process is conducted in four stages: identification, screening, eligibility assessment, and inclusion. These stages are based on the reporting principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). During the identification stage, all articles retrieved from each database are collected.

Duplicate articles are then removed. Next, titles and abstracts are screened based on inclusion and exclusion criteria. Articles that meet the initial criteria are then reviewed in full text to determine their eligibility. Articles that meet all criteria are subsequently included in the meta-analysis.

Data Extraction

Data from articles that met the inclusion criteria were systematically extracted using a data extraction table. The information collected included author names and year of publication, participant characteristics, sample size, intervention characteristics, exercise duration and frequency, comparison groups, instruments for measuring ankle stability or balance, and study results in the form of mean values, standard deviations, and sample sizes. This data was used to determine the effect sizes of each study prior to quantitative synthesis.

Data Analysis

A meta-analysis was conducted by combining the results of studies that met the inclusion criteria. The effect size used was the Standardized Mean Difference (SMD) because the studies analyzed may have used different instruments to measure stability or balance. The SMD value was used to indicate the magnitude of the difference in the effect of proprioceptive exercise on ankle stability compared to the control condition. Each effect size is presented along with a 95% confidence interval (CI).

Heterogeneity among studies was analyzed to determine the degree of variation in the observed effects. Heterogeneity was assessed using the I^2 statistic and Cochran's Q. The I^2 value was used to describe the proportion of variation among studies attributable to heterogeneity, rather than sampling error. Next, the appropriate analytical model was determined based on the characteristics and level of heterogeneity of the studies analyzed.

The meta-analysis results are presented in the form of a forest plot to show the effect sizes of each study along with their confidence intervals and the combined effect estimate. Additionally, a funnel plot was used to evaluate the possibility of publication bias. The analysis results were then interpreted based on the direction and magnitude of the effect sizes as well as their level of significance.

Reporting of Results

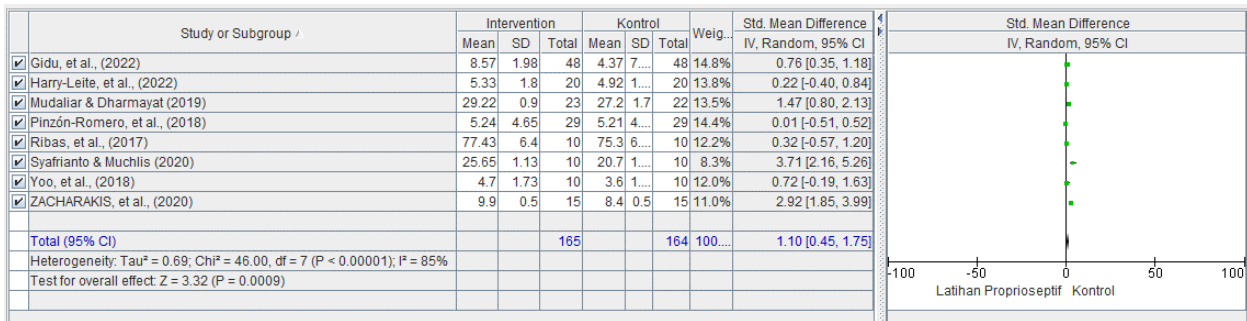
The entire process of identifying and selecting articles was reported using the PRISMA flowchart. Based on this selection process, eight articles that met the inclusion criteria were identified and subsequently used in the meta-analysis. The results of the quantitative synthesis were used to determine the effect size of proprioceptive exercise on improving ankle stability in athletes with CAI.

C. RESULTS AND DISCUSSION

The results of the meta-analysis are presented in the form of a forest plot. A forest plot is a diagram that displays information from each study included in the analysis and an estimate of the overall effect. In a meta-analysis, in addition to the forest plot, a funnel plot is also reported.

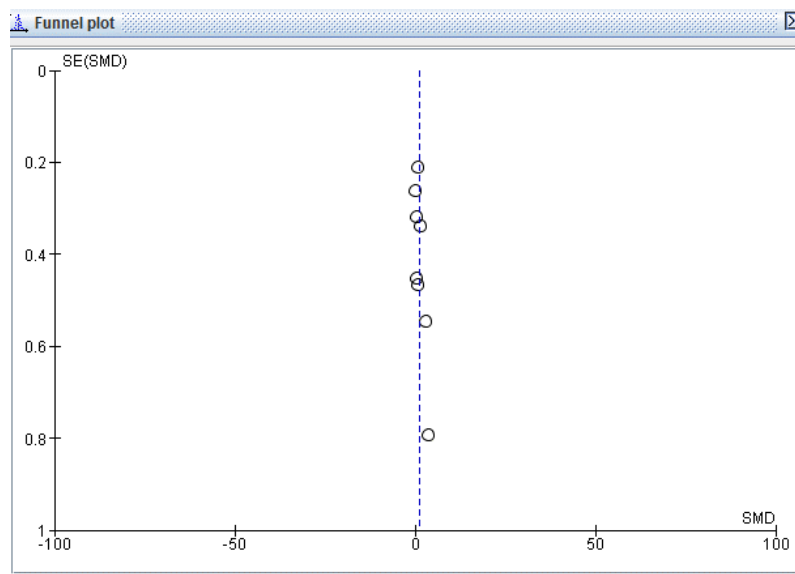
A funnel plot illustrates the potential for publication bias by displaying the relationship between the effect size of the studies and the sample size of the various studies included in the analysis. The presence of publication bias in a funnel plot can be assessed by examining the asymmetry of the funnel shape, as well as the number of data points on the right and left sides relative to the standard error.

Gambar 1. Diagram Forest untuk Latihan Proprioceptif



Based on the analysis in Figure 1, it can be seen that 8 articles reported that proprioceptive exercises can improve ankle stability in cases of Chronic Ankle Instability (CAI) compared to other interventions or no intervention. Meanwhile, there was high heterogeneity among the experiments ($I^2 = 85\%$). The analysis of proprioceptive exercises showed that a 1.10-unit effect size significantly improved ankle stability in cases of Chronic Ankle Instability compared to other interventions or no intervention ($p = 0.0009$).

Gambar 2. Grafik corong Latihan Propripseptif



A funnel plot is a graph that illustrates the estimated effect sizes from each study against their precision estimates, which are typically standard errors. The research findings indicate the presence of publication bias, as evidenced by the asymmetry in the distribution of the plots on the right and left sides: the plots on the left show standard errors ranging from 0 to 0.6, while those on the right have standard errors ranging from 0.4 to 1.

This study analyzed articles that used mean and standard deviation (SD) measures. The results of the systematic review and meta-analysis are presented in the form of forest plots and funnel plots. A forest plot is a diagram that provides an overview of the information from each study included in the meta-analysis and estimates of the overall results. The forest plot also visually displays the degree of variation (heterogeneity) among the study results. A funnel plot illustrates the relationship between a study's effect size and its sample size or the standard error of the effect size across the various studies

examined. As described in the research I conducted, the results indicate that there were 8 research articles serving as the basis for the meta-analysis on the effect of proprioceptive exercise on improving ankle stability in cases of Chronic Ankle Instability (CIA). The plot results indicate that proprioceptive exercise can improve ankle stability in cases of Chronic Ankle Instability (CIA) and that this effect is statistically significant (SMD = 1.10; 95% CI = 0.45 to 1.75; $p = 0.00009$).

Proprioceptive exercises for the ankle can improve both dynamic and static balance and are effective in preventing ankle injuries. It has been stated that ankle proprioception is a crucial component in maintaining balance, as it provides vital information regarding the adjustment of ankle position, which is essential for effective balance control (Ambardini, 2016). The mechanism by which proprioception enhances stability involves afferent signals traveling to the brain from receptors in the body, allowing the brain to determine the body's position. Proprioceptive input is transmitted to the brain via mechanoreceptors, vestibular receptors, and visual receptors. All of this is integrated into the central nervous system. Together, these receptors stimulate efferent motor responses that result in precise body movements.

Ankle proprioception is a crucial component in maintaining balance, as it provides essential information regarding effective ankle position adjustments necessary for balance control (Terada et al., 2013). Ankle proprioceptive training can improve dynamic and static balance and is effective in preventing ankle injuries (Eils et al., 2010). The combination of strengthening exercises and proprioceptive training for functional ankle instability has demonstrated that proprioceptive training has a significant effect on improving functional ankle stability scores.

D. CONCLUSION

Based on the results of a systematic review and meta-analysis of studies that met the inclusion criteria, it can be concluded that proprioceptive exercise has a positive and significant effect on improving ankle stability in athletes with Chronic Ankle Instability (CAI). The meta-analysis results showed a Standardized Mean Difference (SMD) of 1.10 with a 95% CI of 0.45–1.75 and $p = 0.00009$. This value indicates that proprioceptive exercise has a large effect on improving ankle stability in athletes with CAI. Thus, proprioceptive exercise can be considered as a form of exercise intervention in rehabilitation programs and for improving ankle stability in athletes with CAI.

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