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Review

Meta-analysis of the effects of core stability training on handball throwing performance

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ABSTRACT

Objective: To determine the effects of core stability training on throwing performance in handball.
Methodology: A systematic search for trials up to August 2024 was performed in PubMed, Bireme, Scopus and WOS, following the guidelines of the Cochrane Handbook and PRISMA statements. Two reviewers independently selected studies, with disagreements resolved by a third reviewer. The risk of bias was assessed using the ROB2 scale. In addition, study quality was assessed using the clinical trial checklist provided by SIGN. Data were analyzed in RevMan-Web using fixed-effects meta-analysis, assessing heterogeneity with I^2, χ^2 tests and Galbraith plots. Finally, the certainty of evidence was determined employing the GRADE approach.
Results: From 2,343 identified records, 7 studies involving 175 handball players (14–24 years) were selected. Core stability training increased 3.49 kilometer/hour throwing speed from a static position (95 % CI = 1.04 to 5.94), 1.11 kilometer/hour after a run (95 % CI = 0.19 to 2.03) and 1.32 kilometer/hour after a jump (95 % CI = 0.54 to 2.10). The certainty of evidence for these three outcomes was considered low.
Conclusion: Sports scientists (sports doctors, physical therapists, physical trainers, among others) working with handball players might consider the implementation of CST as a valuable tool to help players improve throwing speed.
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Introduction

Handball is a dynamic and highly demanding sport that combines technical, tactical and physical skills to tackle fast game situations and constant contact.[1,2] Within this context, throwing is one of the most important technical skills, since it directly determines the offensive success of the team.[3,4] This sporting gesture is the result of a complex interaction of biomechanical, neuromuscular and physiological factors that allow the generation, transfer and application of force from the proximal segments of the body to the upper limbs, resulting in the necessary speed and precision to overcome rival defenses.[4,5]

The development of upper body strength and power has traditionally been the focus of training aimed at improving throwing performance.[6-8] However, recent studies have begun to highlight the role of core stability as a critical component in optimizing not only throwing performance, but also injury prevention.[9-12] Core stability is defined as the ability of the trunk and pelvic muscles to maintain postural control during functional movements, providing a stable base for the limbs.[13,14] In sports such as handball, where fast actions and changes of direction are frequent, a stable core contributes to the efficiency of movements and efficient transfer of forces, which could improve the athlete's overall performance.[15]

In the sports literature, it has been proposed that core stability training (CST) can positively impact key aspects of performance, including throwing accuracy, speed, and power.[15-18] Nevertheless, studies on this topic in handball players have reported inconsistent results.[15,19,29] Although some authors suggest that a strong core improves throwing biomechanics by providing a stable base for the upper extremities, others have found no significant differences following specific training programs.[15,19,20]

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Exploring the effects of CST on throwing performance in handball has significant implications for both sport science and practical application. From a theoretical standpoint, this line of research provides a better understanding of the relationship between trunk and upper limb biomechanics during throwing, as well as the potential benefits of including core stability exercises in training programs. On a practical level, providing a solid scientific basis on the benefits of this type of training could help sport scientists (physical therapists, sports doctors, physical trainers, among others) to design more effective programs to improve handball performance, while promoting the prevention of musculoskeletal injuries in players.[21]

Therefore, there is a need to consolidate the available evidence on the benefits of CST in the context of handball. This will allow not only to advance the understanding of this topic, but also to provide practical and evidence-based tools to optimize athletes' performance and ensure their safety during sports practice. Consequently, this study aims to determine the effects of CST on throwing performance in handball through a meta-analytical analysis of the published scientific evidence.

Methods

Study design

This study is a meta-analysis of trials to determine the effects of CST on throwing performance in handball. The study was properly registered in the International Prospective Register of Ongoing Systematic Reviews (PROSPERO) under the identification number CRD42024579528. The research focused on the collection of randomized controlled trials and controlled clinical trials, which were analyzed according to the recommendations of the Cochrane handbook[22] and the report followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) list.[23]

Criteria for evaluation of the studies

Types of study

For this study, randomized controlled trials and controlled trials in any language that provided data on the effects of CST on throwing performance in handball were included.

Type of target population

Studies conducted in handball players of all ages, regardless of sex, who had participated in core stability training programs, alone or in combination, were included. Exclusion criteria were established for studies involving athletes from sports other than handball, studies in which the players had an underlying pathology or disability, as well as those in which ergogenic aids were administered that could influence the improvement of ball throwing performance.

Types of interventions

CST protocols, both isolated and combined, involving strength, endurance or power exercises aimed at strengthening core musculature or training core stability. These programs could embrace a wide variety of exercises performed on both stable and unstable surfaces. In addition, exercises could use body self-loading or incorporate external weights. Activities could be dynamic, static or a combination of both.

Types of comparators

As a comparison group, placebo, no training, or any other physical exercise program that did not include core stability exercises or those aimed at strengthening the core musculature as a method to improve handball throwing performance were considered.

Types of outcome measures

This study established handball throwing performance as an outcome measure. This performance could be assessed through the speed of the throw, measured by radar, photocells or high-speed optical cameras, among other devices. Furthermore, it could also be analyzed through scores based on the accuracy of the hits. The objective of this approach was to determine the impact on pitching speed, power and accuracy, aspects that can define pitching performance in players.

Search strategy and procedure

A systematic search for trials was carried out with deadline date August 14, 2024. For this purpose, databases and search engines such as PubMed, Scopus, Web of Science and Bireme were used. The search was optimized using MeSH, DeCS and free terms. The search strategy and the corresponding history for each of the databases and search engines mentioned are detailed in the supplementary material.

Study identification and data extraction

Two reviewers carried out the article selection process, beginning with a preliminary reading of the title and abstract of each manuscript to determine its relevance. Subsequently, both reviewers independently analyzed the full text of the pre-selected articles in depth to select those to be included in the review. In case of discrepancies, a third reviewer was used to resolve any lack of consensus and make a final decision. For this process, the collaborative web/mobile application Rayyan was used.[24]

Once the articles were selected for review, the following data were extracted from each article: title, first author, year of publication, objective, population, methodology, training protocols, outcome measures and findings obtained. It is relevant to note that, in cases where missing data were identified in the manuscripts, the authors were contacted through the email of the corresponding author or through the scientific social network ResearchGate, in order to obtain the required information.

Quality if studies

The quality of the manuscripts included in this systematic review was assessed using the clinical trial checklist provided by the Scottish Intercollegiate Guidelines Network (SIGN).[25] This checklist helped to assess the quality and methodological rigor of each of the selected studies. The application of this scale to the selected articles in this meta-analysis was performed by two investigators. In case of disagreement, a third reviewer was consulted.

Risk of study bias

Each study included in the review underwent an individual assessment of the risk of bias using the Risk of Bias 2 (ROB 2) tool provided by the Cochrane Handbook of Systematic Reviews.[26] Two reviewers performed this assessment independently, analyzing each study to identify potential sources of bias. In case of disagreements between the reviewers, a third reviewer was involved to participate in the discussion and facilitate consensus. Although it was considered to perform an analysis of the risk of publication bias using a funnel plot and Egger's test with the t statistic in STATA,[27] it was decided not to carry it out due to the lack of at least 10 studies, which is the minimum number required to ensure the feasibility of these analyses.[28-30]

Statistical analysis

Data extracted from each study were analyzed following the guidelines of the Cochrane Handbook of Systematic Reviews.[22] For the overall estimate of effect, means (M), mean differences (MD) and standardized mean difference (SMD) were used. In cases where the selected studies did not provide the standard deviation of the outcomes of interest, the corresponding calculation was performed using confidence intervals or standard errors, according to the guidelines of the Cochrane handbook.[22]

Heterogeneity analysis

RevMan web software was used to assess the statistical heterogeneity of the studies, applying statistical methods such as I^2 and χ^2, along with their degrees of freedom and *p* values, in the fixed-effects model. Moreover, Tau^2 was used in the random-effects model. In meta-analyses where moderate or high heterogeneity (I^2 between 40 and 60 % and 60–100 %, respectively) was identified, Galbraith plots or radial regression plots were produced to identify the studies that contributed most to such heterogeneity.[31] These graphs facilitated the sensitivity analysis of meta-analyses with moderate or high heterogeneity, ensuring maximum methodological rigor in the selection of studies to be included in each measure and avoiding ambiguities or arbitrary selections of studies to be included in the meta-analysis. Radial regression plots were developed using STATA statistical software.[27]

Sensitivity analysis

A sensitivity analysis was performed, which consisted of repeating the measurements under different decisions. During this process, several aspects were modified, such as individual and combined exclusion of studies in each phase, taking into account statistical heterogeneity and relying on radial regression plots. Additionally, both random-effects and fixed-effects models were used to assess the robustness of the results.

Methods of results synthesis

For the analysis and synthesis of the effect of the intervention, heterogeneity and comparability between studies were considered as fundamental pillars. The meta-analytic analyses were performed only with homogeneous studies or studies with low statistical heterogeneity using the fixed effects model in Revman Web. This made it possible to determine the combined effect of the studies on the variables of interest, guaranteeing the rigor and veracity of the data by avoiding the comparison of studies that were not compatible with each other.

Assessment of the certainty of evidence

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach[32] was used to determine the certainty and strength of recommendation of the outcomes obtained in this meta-analysis. Two reviewers performed independent assessments of certainty using the official GRADEpro website, and in case of disagreement, a third reviewer was consulted to resolve discrepancies.

Results

Study selection

From the database search, 2343 articles were initially identified. After eliminating duplicates, 1014 manuscripts were obtained. Subsequently, the titles and abstracts were evaluated, allowing 13 studies to be selected for a more detailed full-text review. Of these, 6 were excluded due to the use of an inappropriate outcome measure.[15,18-20,33,34] Finally, 7 articles were included in this systematic review with meta-analysis (Fig. 1).[35-41]

Characteristics of the included studies

The seven studies included in this review were published between 2011 and 2023, with a total sample of 175 handball players, whose ages ranged from 14 to 24 years. Within this sample, 90 handball players participated in the intervention group and 85 in the control group. Of the 175 handball players, 99 were female and 76 were male. The studies adopted a variety of dosages and training strategies, with some implementing a 6-week program,[36,38,39,41] others an 8-week program,[35,37] and one extended for 10 weeks.[40] Most studies conducted the training

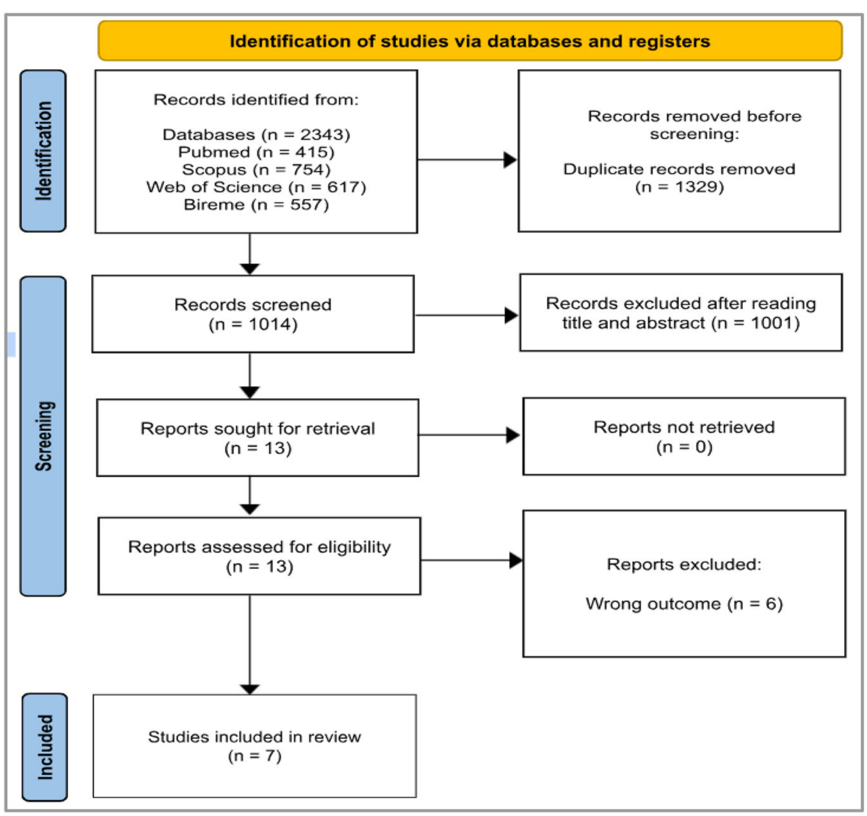

Fig. 1. Resumen de la búsqueda y selección de estudios.

sessions twice per week,[37-39,41] while three studies scheduled them at 3 and 4 times per week, respectively.[35,36,40]

Regarding training methodology, studies employed both unstable surfaces[37,39] and a combination of stable and unstable surfaces.[35,38,40,41] In addition, a diversity in exercise approaches was observed, with some studies focusing on pure dynamic exercises,[37-41] while others combined dynamic and static exercises.[35,36] Notably, no study was limited exclusively to static exercises. Table 1 summarizes the highlights of each of the studies included in this investigation.

Quality of the studies

The quality of the studies, evaluated using the clinical trial checklist proposed by SIGN, showed that six studies were classified as acceptable quality[35-40] and one as low quality[41] (Table 2). It was highlighted that no study complied with item 1.4, related to the blinding of both study subjects and investigators and evaluators. However, it is recognized that, given that the intervention in question is physical exercise, implementing blinding of the population and of the investigators responsible for the training program may be particularly challenging.

Risk of study bias

After applying the ROB 2 tool to assess the risk of bias in the included studies, it was determined that 100 % of the studies had a low risk of bias in the domains “Deviations from intended interventions” and “Mising outcome data” (Fig. 2). In the domain “Measurement of the outcome” and “Selection of the reported outcome”, 100 % of the studies showed some concerns, because the assessors were aware of the intervention that the population received and because no study was adequately registered with access to its protocol. This was an impediment to verify whether the studies followed a pre-specified plan. Fig. 2 shows the individual risk of bias assessment for each of the 7 included studies.

Effects of the intervention on throwing performance in handball

In the selected studies, throwing performance was assessed exclusively by throwing speed,[35-41] considering three main conditions, firstly, speed from a static position; secondly, speed after a short run; and finally, speed following the execution of a jump, i.e., a jump throw with a jump. It should be noted that no study used an alternative method to assess performance, such as throwing accuracy, which could provide a complementary perspective. To facilitate a better comprehension of the effect, the results are presented broken down according to the type of throw, speed from a static position, speed after a short run and speed after a jump.

Effects on throwing speed from a static position

For the outcome measure related to throwing speed from a static position, 5 studies were identified for possible meta-analytic analysis.[35,36,38,40,41] The statistical heterogeneity analysis revealed high heterogeneity (Fig. 3), with a I^2 value of 83 % and a χ^2 of 23.36, which exceeds four times the degrees of freedom, with a *p* value was 0.0001, suggesting a high presence of heterogeneity. Consequently, we chose to perform a sensitivity analysis using Galbraith plots or radial regression plots to identify which studies contributed to heterogeneity. The radial regression plot showed that the study by Ozmen et al.[31] and Saeterbakken et al., ,[41] were the most heterogeneous studies (Fig. 4). Therefore, it was decided to withdraw these studies and perform a reanalysis.

Meta-analytic reanalysis, after adjustment, revealed low statistical heterogeneity (Fig. 5), with a I^2 value of 0 % and a χ^2 of 0.86, which exceeds the degrees of freedom by less than half. Furthermore, a *p* value of 0.65 was obtained, suggesting a possible absence of heterogeneity. Based on this reanalysis, it was considered appropriate to report the effect of the intervention on this outcome by meta-analysis, as synthesizing results from non-comparable studies could lead to spurious or incorrect conclusions by overestimating the true effect.

Finally, for this outcome measure, 3 studies were included,[35,36,40] with a total of 43 players in the intervention group and 38 in the control group. Considering that Saeterbakken et al[41] had reported the outcome using the unit of measurement meters/second and the other studies kilometer/hour, the standardized mean difference was used in the first analysis (Fig. 3). Nevertheless, in the reanalysis in the absence of the study by Saeterbakken et al.[41] the mean difference was used. There it was found a mean difference of 3.49 kms/hour increased in throwing speed from a static position (95 % CI =1.04 to 5.94) with a *p* value of 0.005, which evidences a statistically significant effect in favor of the

Table 1
Characteristics of the included studies.

Author	Year	Type of study	Intervention group (CST + DT)	Control group (DT)	Game Level	Core stability training program				
						# weeks	Frequency	Training surface	Type of exercises	# exercises
Šagát[35]	2020	Randomized clinical trial	n: 15 female handball players (18.7 ± 2 years)	n: 10 female handball players (18.7 ± 2 years)	Professional	8	3	Stable/ Unstable	Dynamics/ statics	7
Bauer[36]	2022	Randomized clinical trial	n: 13 male handball players (16.9 ± 0.6 years)	n: 13 male handball players (17.2 ± 0.8 years)	Amateur	6	3	Stable	Dynamics/ statics	3
Dahl[37]	2021	Randomized clinical trial	n: 13 female handball players (19.5 ± 2.0 years)	n: 13 female handball players (19.5 ± 2.0 years)	Professional	8	2	Unstable	Dynamics	4
Ozmen[38]	2020	Randomized clinical trial	n: 10 male handball players (14.9 ± 0.31 years)	n: 10 male handball players (14.90 ± 0.56 years)	Amateur	6	2	Stable/ Unstable	Dynamics	4
Larissa[39]	2019	Randomized clinical trial	n: 10 female handball players (24.1 ± 3.8 years)	n: 10 female handball players (23.7 ± 5.2 years)	Amateur	6	2	Unstable	Dynamics	9
Manchado[40]	2017	Randomized clinical trial	n: 15 male handball players (18.5 ± 3.0 years)	n: 15 male handball players (18.9 ± 3.8 years)	Amateur	10	4	Stable/ Unstable	Dynamics	7
Saeterbakken[41]	2011	Non-randomized clinical trial	n: 14 female handball players (16.6 ± 0.3 years)	n: 10 female handball players (16.6 ± 0.3 years)	Professional	6	2	Stable/ Unstable	Dynamics	6

Abbreviations = CST: Core Stability Training; DT: Daily Training.

Table 2
Quality of the studies according to the SIGN checklist.

CLINICAL TRIALS CHECKLIST											
Study/ Items	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	2.1	2.2
Šagát[35]	✓	✓	?	?	✓	✓	✓	0 %	✓	Na	Acceptable	✓
Bauer[36]	✓	✓	?	?	✓	✓	✓	0 %	✓	Na	Acceptable	✓
Dahl[37]	✓	✓	?	?	✓	✓	✓	0 %	✓	Na	Acceptable	✓
Ozmen[38]	✓	✓	?	?	✓	✓	✓	0 %	✓	Na	Acceptable	✓
Larissa[39]	✓	✓	?	?	✓	✓	✓	0 %	✓	Na	Acceptable	✓
Manchado[40]	✓	✓	?	?	✓	✓	✓	0 %	✓	Na	Acceptable	✓
Saeterbakken[41]	✓	X	X	X	✓	✓	✓	0 %	✓	Na	Low quality	X

Abbreviations = Na: Not applicable; ✓: Yes; X: No; ?: Can’t say.

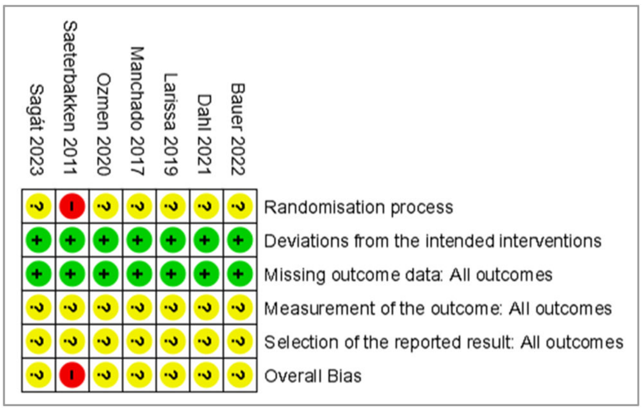

Fig. 2. Summary of risk of bias.

intervention group that participated in CST trainings (Fig. 5).

Effects on throwing speed after a race

For this outcome measure related to throwing speed after a run, 4 studies were identified for possible meta-analytic analysis.[35,37,38,40] Statistical heterogeneity analysis revealed low heterogeneity (Fig. 6), with a I^2 value of 0 % and a χ^2 of 2.41, which does not exceed the degrees of freedom, with a p value of 0.49, suggesting a possible absence of heterogeneity. Consequently, a sensitivity analysis with radial regression plots was not performed, considering that the studies are homogeneous with respect to each other. That being said, a total of 53 players were included in the intervention group and 48 in the control group. It was found a mean difference of 1.11 kilometer/hour increased in throwing speed after a run (95 % CI = 0.19 to 2.03) with a p value of 0.02, evidencing a statistically significant effect in favor of the intervention group that participated in CST trainings (Fig. 6).

Effects on throwing speed after a jump

For this outcome measure related to throwing speed after a jump, 4 studies were identified for possible meta-analytic analysis.[35,37,38,40] Statistical heterogeneity analysis revealed low heterogeneity (Fig. 7), with a I^2 value of 19 % and a χ^2 of 3.72, which does not exceed the degrees of freedom, with a p value of 0.29, suggesting a possible absence of heterogeneity. Consequently, a sensitivity analysis with radial regression plots was not performed, considering that the studies are homogeneous with respect to each other. That being said, a total of 53 players were included in the intervention group and 48 in the control group. It was found a mean difference of 1.32 kilometer/hour increased in throwing speed after a jump (95 % CI = 0.54 to 2.10) with a p value of 0.0010, evidencing a statistically significant effect in favor of the intervention group that participated in CST trainings (Fig. 7).

Assessment of the certainty of evidence

The certainty of the evidence was evaluated using the official

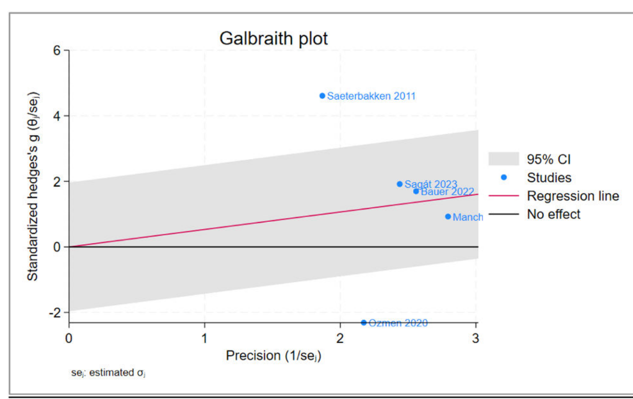

Fig. 4. Galbraith diagram for throwing speed from a static position.

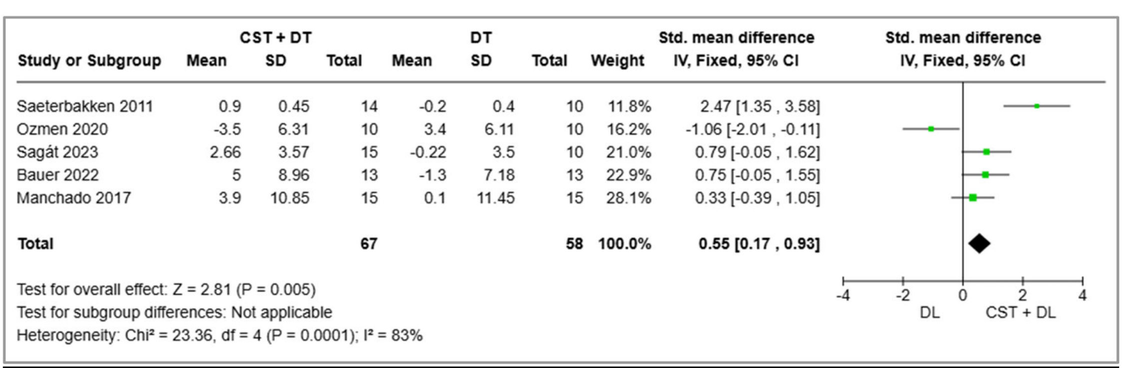

Fig. 3. Initial forest plot without sensitivity analysis for throwing speed from a static position. Abbreviations = CST: Core stability training. DT: Daily training.

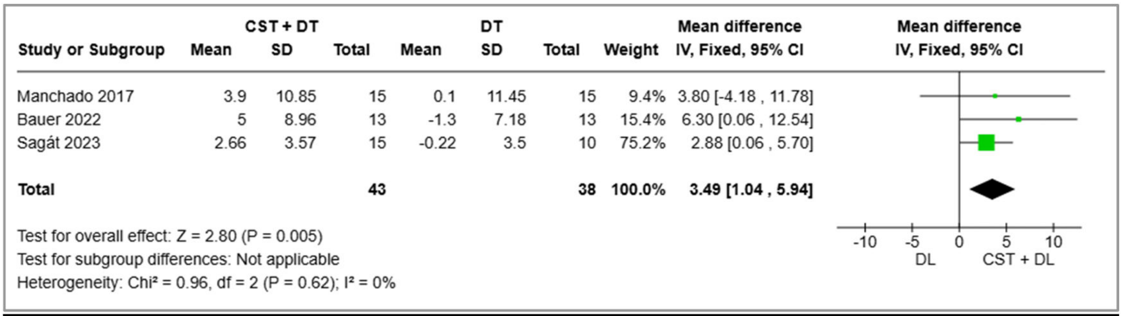

Fig. 5. Forest plot comparing the effect of core stability training combined with daily training versus daily training on throwing speed from a static position. Abbreviations = CST: Core stability training. DT: Daily training.

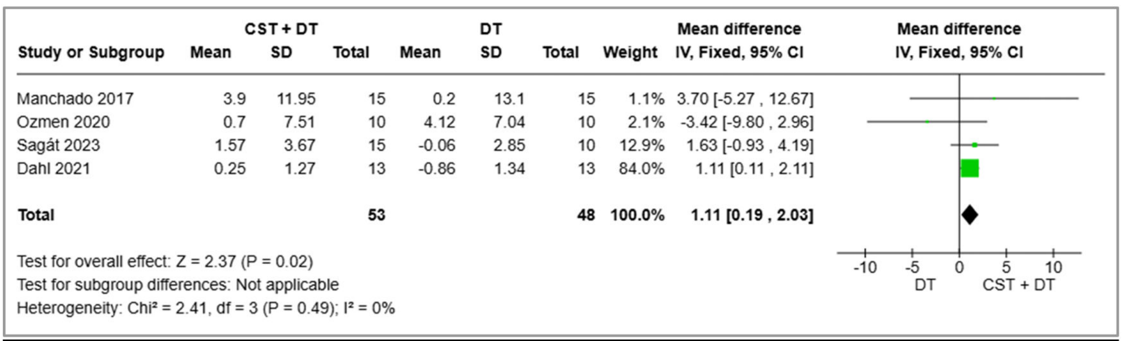

Fig. 6. Forest plot comparing the effect of core stability training combined with daily training versus daily training on throwing speed after a run. Abbreviations = CST: Core stability training. DT: Daily training.

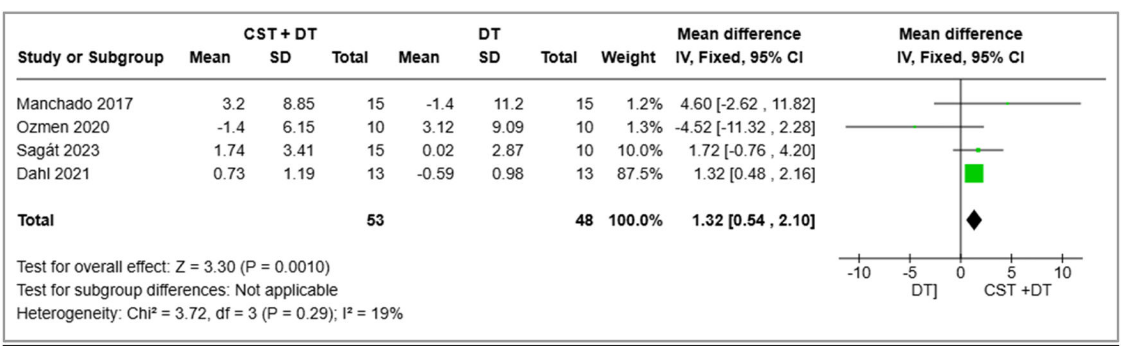

Fig. 7. Forest plot comparing the effect of core stability training combined with daily training versus daily training on throwing speed after a jump. Abbreviations = CST: Core stability training. DT: Daily training.

Table 3
Evaluation of the certainty of evidence under the GRADE approach.

Certainty assessment						Nº of handball players		Effect	Certainty	Importance
Nº of studies	Risk of bias	Inconsistency	Indirect evidence	Inaccuracy	Other considerations	CST + DT	DT	Absolute (95 % IC)		
Throwing speed from a static position										
3	Serious	Not serious	Not serious	Serious	None	43	38	DM 3,49 more speed (1.04, 5,94)	⊕⊕⊙⊙ *Low*	IMPORTANT
Throwing speed after a run										
4	Serious	Not serious	Not serious	Serious	None	53	48	DM 1,11 more speed (0.19, 2.03)	⊕⊕⊙⊙ *Low*	IMPORTANT
Throwing speed after a jump										
4	Serious	Not serious	Not serious	Serious	None	53	48	DM 1.32 more speed (0.54, 2.10)	⊕⊕⊙⊙ *Low*	IMPORTANT

Abbreviations= CST: Core Stability Training. DT: Daily training.

GRADEpro platform (Table 3). The results showed that the certainty for performance in throwing speed from a static position was rated as low. Similarly, both throwing speed after a run and throwing speed after a jump were also rated as low certainty. This rating was first due to a risk of bias considered serious, as all studies presented at least some concerns. Second, the imprecision domain was also rated as serious, due to the obvious limitations associated with small sample sizes. However, it is important to interpret these results in context. Given that these studies are conducted in small teams, making it difficult to obtain large samples after randomization, and without this review, the effect estimates would have been based on even smaller sample sizes, significantly limiting the validity and applicability of the findings.

Discussion

This systematic review with meta-analysis constitutes a pioneering effort in the investigation of the effects of CST on throwing performance in handball. To our knowledge, it is the first review to address this specific topic, contributing novel and relevant evidence to the field of sport. The results reveal statistically significant improvements in throwing performance among players who incorporated CST into their routines compared to those who did not. These findings are aligned with previous studies that documented benefits of CST on physical performance variables in athletes from different disciplines and in healthy individuals.[42-44] However, whereas previous research focused predominantly on cross-sectional tests of performance, such as jumping or running speed, this review broadens the horizon by focusing on sport-specific performance.

For instance, Saeterbakken et al.[42] reported significant improvements in running speed, with an average reduction of 0.66 standard deviation units (95 % CI = 0.20, 1.12), representing a medium-sized effect according to Cohen's criteria.[45] Similarly, Rodriguez-Perea et al[44] found reductions of 1.12 standard deviation units (95 % CI = 0.32, 1.92) in speed tests in multiple sport disciplines, including handball, classified as a large effect.[45] This same meta-analysis also documented improvements of 0.74 standard deviation units (95 % CI = 0.42, 1.06) in specific jumping tests, reinforcing the idea that CST not only prevents injury and supports rehabilitation, but also optimizes key physical performance variables.

In the field of throwing, Dong et al[43] reported statistically significant improvements in medicine ball throwing speed in wrestlers, with a standardized mean difference of 0.39 units (95 % CI = 0.06, 0.72; $p = 0.02$), findings that support our results in handball players. Moreover, research in other disciplines such as soccer has indicated that CST improves long-distance shooting performance. For example, a significant increase in distance achieved with the non-dominant leg was observed after core stability training ($p = 0.001$), while control groups showed no relevant changes ($p = 0.832$).[46] These similarities reinforce the plausibility that CST is an effective and versatile intervention, capable of influencing specific performance variables according to the demands of each sport discipline.

The findings presented raise new research questions focused on specific performance in handball. While this study addresses throwing, it is crucial to explore whether CST could also improve other critical variables, such as agility, speed, and overall strength, given that these have already shown substantial improvements in other sports.[47] This research could position CST as a comprehensive training approach that also strengthens the overall musculoskeletal and nervous system.

From a theoretical perspective, these results are consistent with the principles of biomechanics and kinetic chain theory. Stability and core strength play an essential role in the efficient transfer of force from the torso to the limbs. Inadequate stability can compromise this transfer, reducing peripheral force generation and decreasing the efficiency of movement patterns.[48] According to kinetic chain theory, any disruption in muscle connections either due to fatigue or insufficient motor control can generate energy losses and limit the execution of complex movements that require high levels of physical performance.[49] This is evidenced in studies such as that of Rosemeyer et al.[50] which demonstrated how fatigue of the core musculature affects force-generating capacity in all planes of movement. Furthermore, additional research has linked a well-conditioned core to improvements in specific activities such as running and explosive force production.[51]

Collectively, the results of this review suggest that CST could be a key tool not only to optimize sport performance in specific modalities such as handball, but also to comprehensively address the physical demands of athletes. Future research should focus on standardizing training protocols and evaluating specific long-term outcomes, with the aim of consolidating its role as a fundamental strategy in sports training.

Conclusion

It has been demonstrated that implementing CST for a minimum of six weeks is effective in improving throwing velocity in handball., with increases of 3.49 kph from a static position (95 % CI = 1.04 to 5.94), 1.11 kph after a run (95 % CI = 0.19 to 2.03) and 1.32 kph after a jump (95 % CI = 0.54 to 2.10). These results highlight the potential of CST as a specific training strategy to optimize performance in one of the fundamental skills of handball. In this way, sport scientists (sport doctors, physical therapists, physical trainers, among others) working with handball players could consider the implementation of CST as a valuable tool to help athletes reach their competitive goals.

However, although current findings focus on throwing speed, a crucial component of performance in this sport, the impact of CST on other equally relevant aspects, such as accuracy and shooting effectiveness, is still unknown. This underscores the need for future research that addresses these knowledge gaps. Furthermore, it is imperative to evaluate how CST influences other cross-cutting physical performance tests, such as jumping, speed, agility, and balance, thus broadening its applicability and understanding in the sport context. Finally, future studies should investigate how manipulation of specific CST variables, such as exercise progressions and training loads, can maximize its benefits.[52] This approach, aligned with the fundamental principles of sport training, will allow the development of more effective and personalized programs that further enhance the sport performance of handball players and other disciplines.

Statement

(1) Conflict of Interest: None known
(2) Ethical Approval: Not applicable
(3) Funding: The University Foundation for Health Sciences funded this research, enabling its successful development.
(4) That it is an original work.
(5) That it has not been previously published in whole or in part.
(6) That it is not under evaluation in any other publication.
(7) That all authors are responsible for the final version of this article, to the preparation of which they have contributed.
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Conflicts of interest

None.

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