

Bachelor Thesis

Physical Therapy

The Relationship between Core
Stability and Athletic Performance

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Does improved core stability acquired through specific interventions enhance the outcome on athletic performance tests in athletes?

Abstract

Objective: To review the relationship between 'core stability' and athletic performance. A secondary objective was to assess which functional performance tests can be used to measure core stability and athletic performance.

Method: PubMed and the Cochrane Library were searched to find articles related to 'core stability' and/or 'core strength' and athletic performance. (1980-2013)

Results: Interventions targeted to enhance performance test outcomes after a core stability intervention program showed mixed results. Static core stability test outcomes show no significant relationship with conventional performance test outcomes. Dynamic core stability test outcomes show a significant relationship with athletic performance.

Conclusion: Though results are diverse, dynamic sport specific core stability interventions show promise of a significant relationship between core stability and athletic performance. The lack of consensus on definitions, measurements and interventions pose difficulties. A 'one size fits all' approach towards core stability tests and performance tests is not feasible. Sport specific performance tests should be designed and used to measure the potential impact of core stability.

Keywords: core stability, core strength, athletic performance

Abstract (Dutch)

Doel: Dit artikel onderzoekt de relatie tussen 'core stability' en atletische prestaties. Een secundair doel is het beoordelen welke functietesten gebruikt kunnen worden bij het meten van core stability en atletische prestaties.

Methode: PubMed en de Cochrane Library zijn doorzocht op artikelen gerelateerd aan 'core stability' en/ of 'core strength' en atletische prestatie (1980-2013)

Resultaten: Interventies die poogden de resultaten op functionele prestatietests te beïnvloeden door middel van een core stability programma laten conflicterende resultaten zien. Uitkomsten van statisch uitgevoerde core stability tests tonen geen significante relatie aan met conventionele prestatietest uitkomsten. Als core stability gemeten wordt met een dynamische core stability test, lijkt er wel een significante relatie tussen core stability en atletische prestatie aantoonbaar.

Conclusie: Ondanks conflicterende resultaten betreffende core stability interventies en het verbeteren van atletische prestaties, tonen sport specifieke core stability interventies een significante relatie aan tussen core stability en atletische prestatie. Het gebrek aan overeenstemming betreffende definities, meetinstrumenten en interventies veroorzaakt moeilijkheden. Een "one size fits all" aanpak is niet bruikbaar voor core stability en prestatie testen. Sport specifieke atletische prestatie testen en interventies betreffende core stability alsmede meer onderzoek hiernaar worden aanbevolen.

Trefwoorden: core stability, core kracht, atletische prestatie

Introduction

Core stability has become immensely popular and is widely used in the athletic sector. The general opinion is that 'core stability' and 'core strength' not only prevent injury but also enhance athletic performance. Core stability training has shown to reduce low back pain (McGill, 2001). However, its effectiveness in enhancing sports performance remains unclear since it has not yet been subject to a systematic review.

Definition of Core Stability

There is no worldwide consensus about the definition of core stability. Different terms are used in both the rehabilitation sector and the athletic sector. In the rehabilitation sector the main definition used, is the one suggested by Panjabi. Panjabi (Panjabi, 1992) describes core stability as 'the integration of the passive spinal column, active spinal muscles, and the neural control unit, which when combined maintains the intervertebral range of motion within a safe limit to enable activities to be carried out during daily living'. In this definition, daily living does not necessarily include sports activities, because the required level of stability and strength of the core is different than that of an athlete (Leetun, Ireland, Willson, Ballantyne, & Davis, 2004). This has resulted in different definitions of core stability that are more suitable for sports activities.

Kibler *et al.* (Kibler, Press, & Sciascia, 2006) summarize core stability as 'the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated athletic activities'. Tse *et al.* (Tse, McManus, & Masters, 2005) leaves out the passive component and describes it as follows: 'The core musculature includes muscles of the trunk and pelvis that are responsible for maintaining the stability of the spine and pelvis and are critical for the transfer of energy from the larger torso to smaller extremities during many sports activities'. These definitions expand the definition of Panjabi to an athletic level, suggesting higher loads and more effective energy transfers from and to the extremities through the core.

Bergmark (Bergmark, 1989) combines the definition given by Panjabi and others by dividing the trunk muscles into 'local muscles' and 'global muscles'. The local muscles (as described by Panjabi) attach to the spine and have a direct influence on inter-segmental movement and stability while the global muscles attach to the hip and pelvis providing mobility and proper orientation of the spine. Bergmark theorized that maintaining a balance between those two groups is important, stating that if one lacks control of the local muscles, the global muscles have to compensate for the segmental instability, resulting in inefficiency.

The term 'core strength' is also often used as means of describing core stability. Like core stability, there is no consensus on the definition core strength. Core strength can be defined as the ability of a muscle to hold a neutral stable position. For example, one measure of core strength is the duration for which an individual can hold a stable prone position. In case of core stability, this 'plank position' is also often used as a core stability test. Core strength is also described as the ability to hold the core still and stable while moving the extremities. To broaden the search for as many articles involving the use of the core to enhance stability, the term 'core strength' has also been included in the literature search. Due to the lack of consensus on the definition of 'core stability', this review will only include the definitions mentioned above.

Core Stability and Performance

It is theorized that improving core stability and the resulting higher efficiency in the transfer of energy from the trunk to the extremities will result in improved performance (Tse et al., 2005). Performance can be interpreted in different ways. In the rehabilitation sector, different performance goals are pursued, in particular functioning pain free and being able to do every day, low-load tasks (Hides, Jull, & Richardson, 2001). In the athletic sector, performance can be characterized as the ability to run faster, throw further, jump higher, etc. Multiple variables are involved in athletic performance, including the fitness level of the athlete, technique and it can even include the higher attendance of training and or match days as a result of less injuries. In the athletic sector arguments can be made that in the end, the ultimate performance goal is winning sports matches.

Performance can be measured through functional tests. Conventional tests, such as the Shuttle run test, the 40-yard dash, the vertical jump, etc. have a less defined core component. Furthermore, these tests are not specific for all sports. More popular are the Star Excursion Balance Test (SEBT) and the Medicine Ball Throw Test (MBTT), which are more sport specific. The SEBT correlates more to lower extremity focused sports such as soccer and running. The MBTT correlates more to upper extremity focused sports such as handball and basketball.

Examples of other performance measures are: the 5000m run, the 20-yard dash, 1-RM Squat, bench and hang clean tests. The 5000m run test is specific for long distance runners, the 40-yard dash for sprinters. A different level and type of core stability is needed for different sports, e.g. a baseball player needs a different type of core stability than a rower. Moreover, an Olympic athlete requires a different level of core stability than a recreational player.

This review will examine whether improved core stability will result in an enhanced athletic performance and whether it affects performance on functional tests. Moreover, it will assess which tests are most suitable to measure core stability and athletic performance.

Methods

A literature study was conducted searching PubMed and the Cochrane Library. A Boolean phrase was used: 'Core strength' OR 'Core stability' AND 'Performance'.

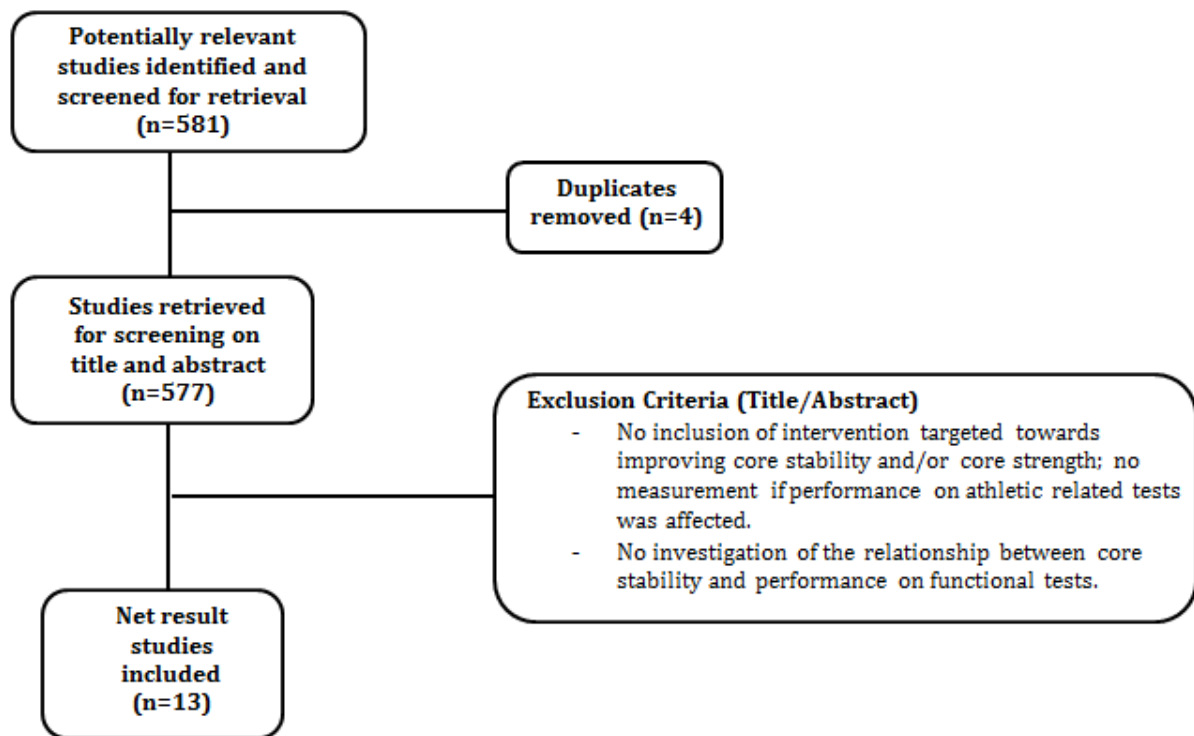


Figure 1: Flowchart Search

Articles were included when the researchers performed an intervention targeted towards improving core stability and/or core strength and measured whether performance on athletic or functional tests was affected. Other articles included were those that investigated the relationship between core stability and performance on functional tests indicating whether or not core stability might be a significant contributor.

Methodological quality of Randomized Controlled Trials (RCTs) was scored using the Physical Therapy Evidence Database (PEDro) scale (Centre for Evidence-Based Physiotherapy, The George Institute for Global Health, University of Sydney) (Maher, Sherrington, Herbert, Moseley, & Elkins, 2003). Scores were assigned based on 10 criteria described in **Appendix 1**.

There is a lack of worldwide accepted tools for quality assessment concerning observational studies (OBS). This is hampered further by the lack of complete and accurate reporting in OBS. 'The 'STrengthening the Reporting of OBservational studies in Epidemiology' (STROBE) statement represents a step towards improving the reporting of OBS' (Sanderson, Tatt, & Higgins, 2007) (Mallen, Peat, & Croft, 2006). The statement and the top 15 criteria mostly used to assess the quality of OBS found in the review from Mallen have provided the tools to create a scoring format for OBS. An article can have a maximum score of 10. A score of ≥ 6 indicates high quality correlation studies. The scoring format can be found in **Appendix 2**.

Additional studies, such as brief reviews, were analysed only to further illustrate the performance enhancing effect of core stability.

After scoring the methodological quality of the studies, a best evidence synthesis was applied. The synthesis according to Van Peppen (Van Peppen et al., 2004) was modified to account for the observational studies used in this article. The Controlled Clinical Trials (CCTs) in Van Peppen's Best Evidence Synthesis have been replaced with OBS to better suit the needs of this review (**Table 1**).

Table 1: Best evidence synthesis Van Peppen et al.

'Best-evidence synthesis' Van Peppen et al. (2004)	
Strong Evidence	Based on statistical significant results measured in at least 2 RCTs of high quality, with PEDro scores ≥ 4
Moderate Evidence	Based on statistical significant results measured in at least 1 RCT of high quality and at least 1 RCT of low quality (≤ 3 points on PEDro) or 1 CCT of high quality
Limited Evidence	Based on statistical significant results, measured in at least 1 RCT of high quality or at least 2 CCTs of high quality (in absence of RCTs of high quality)
Probable evidence	Based on statistical significant results, measured in at least 1 CCT of high quality or RCT of low quality (in absence of high quality RCTs)
None or insufficient evidence	In some cases where results of included studies don not conform to levels of evidence as mentioned above, or in cases that show conflicting (statistical significant positive and statistical significant negative) results are present between RCTs and CCTs, or in cases where no studies could be included

RCT = Randomized Controlled Trial, CCT = Controlled Clinical Trial

Results

The literature search yielded 572 articles in PubMed. After title and abstract screening, 13 articles were included for further analysis. The same Boolean phrase was used searching The Cochrane Library, which resulted in 9 articles (0 Cochrane reviews, 9 trials). After title and abstract screening, 5 articles were excluded. The remaining 4 were also found in the PubMed search.

A total of 4 RCTs that described a core stability intervention program were included for final analysis. Two RCTs scored 5 and two RCTs scored 6 on the PEDro scale (**Table 2**). The average PEDro score for the RCTs was (mean $\pm$ SD) 5.5 ± 0.5 .

The results of the RCTs suggest a relationship between core stability and athletic performance with three out of four reporting a significant outcome. Sato (Sato & Mokha, 2009) reported a significant difference in 5000m run times between the group that underwent additional core stability training (CST) and the group that continued with only regular training. The CST group improved their scores with an average of 47 seconds. The control group that continued regular training demonstrated a 17 second increase.

Saeterbakken (Saeterbakken, van den Tillaar, & Seiler, 2011) found that after a 6 week period of 2 times a week Sling Exercise Training (SET) next to regular training the maximum throwing velocity of female handball players improved with 4.9% ($p < 0.01$) compared with the control group that did not receive additional core stability training.

Filipa (Filipa, Byrnes, Paterno, Myer, & Hewett, 2010) performed an intervention twice a week, consisting of progressive core stability exercises that were added to soccer athletes training programmes for a period of 8 weeks. The SEBT pre-test results between the CST group and the control group who continued regular sports training showed no significant differences. At the post-intervention SEBT, the scores of the CST group improved with an average of 8.1% on the right leg and 6.5% on the left leg. The control group showed no significant post-test changes. Neuromuscular training that focused on core stability significantly improved the composite SEBT scores in female soccer players when compared to the control group.

Tse *et al.* (Tse *et al.*, 2005) performed a twice a week intervention for the duration of 8 weeks. The intervention consisted of progressive core stability exercises that gradually moved from static to dynamic. No significant changes on any of the performance tests were measured. The conducted intervention, performance measures and results of the included RCTs can be found in Table 2.

The correlation studies were scored with the quality tool based on the STROBE statement. The quality assessment tool can be found in **Appendix 2**. The scoring resulted in an average of (mean $\pm$ SD) 6.75 ± 1.25 . The correlation studies show mixed results. Sharrock (Sharrock, Cropper, Mostad, Johnson, & Malone, 2011) examined the relationship between scores on a core stability test and multiple conventional performance tests on a group of athletes with various sports backgrounds. Apart from the Medicine Ball Throw no significant relation was found. Nesser (Nesser, Huxel, Tincher, & Okada, 2008) found significant but weak and inconsistent correlations between scores on core stability and performance tests in a group of college level football athletes. Shinkle (Shinkle, Nesser, Demchak, & McMannus, 2012) also performed core stability tests and performance tests on a group of football athletes and found significant correlations, suggesting a relationship does exist. Keogh (Keogh, Aickin, & Oldham, 2010) performed a 1 repetition maximum (1RM) shoulder press test with stable and unstable undergrounds on resistance trained men. No significant correlations were found. Correlation studies measures and outcomes are presented in **Table 3**.

Both significant positive and negative results were found in RCTs and OBS. Using the modified Best Evidence Synthesis, the results showed insufficient evidence for the enhancing effect of core stability on athletic performance. The diversity of measuring tools and performed interventions of the studies made clustering of outcome data impossible.

Table 2: Randomized Controlled Trials

Study	Year	Sport	Intervention	Performance Measures	Results		PEDro
					Core Stability Group	Control Group	
Filipa <i>et al.</i>	2010	Soccer	8 weeks: 2/w phases of progressive exercises added to regular training	SEBT	Right Limb: 96.5% to 104.6% Left Limb: 96.9% to 103.4%	No change No change	4
Saeterbakken <i>et al.</i>	2011	Handball	6 weeks: 2/w SET added to regular training	Max. Throwing velocity	+ 4.9%	No change	6
Sato <i>et al.</i>	2009	Running	6 weeks: 4/w SB exercises added to regular training	5000m run, SEBT, GRF	5000m run + 47 sec SEBT +21.92cm	5000m run + 17 sec SEBT +10.25cm	5
Tse <i>et al.</i>	2005	Rowing	8 Weeks: 2/w phases of progressive exercises added to regular training	2000m REM test, Vertical Jump, 10-m shuttle run, 40-m sprint, 2kg MBT test, McGill tests	No change	No change	4

PEDro= Pedroscore (max. 10), SEBT= Star Excursion Balance Test, GRF= Ground Reaction Force, CST= Core Stability Training, SET= Sling Exercise Training, SB= Swiss ball, REM= Rowing Ergometer, MBT= Medicine Ball Throw test, McGill tests= McGill core stability tests

Table 3: Observational Studies

Study	Year	Sport	Performance Measures	Results	Score
Keogh <i>et al.</i>	2009	Resistance Training	Core Test: Endurance Assessment 1RM SP 1RM on SB	No significant between-group differences	8
Nesser <i>et al.</i>	2008	Football	Core Test: McGill protocol Bench Press 1RM Squat 1RM Power Clean 1RM 20yd sprint 40yd sprint Shuttle run CM Vertical Jump	Significant correlations ranging from weak to moderate, but inconsistent	6
Sharrock <i>et al.</i>	2011	Basketball Soccer Tennis Volleyball Swimming	Core Test: DLLT 40-yd dash T-test MB Throw Vertical Jump	DLLT: Male 47.43 % Female: 54.75% No significant correlation on 40-yd dash, T-test, Vertical Jump MB Throw significant correlation with core strength: 0.389	6
Shinkle <i>et al.</i>	2012	Football	Core Test: MB Throws Squat 1RM Bench Press 1RM CM Vertical Jump 40yd sprint Proagility run	Correlations between MB throws (static and dynamic) and performance variables suggest core does have a relationship with performance	7

DLLT= Double Leg Lowering Test, MB= Medicine Ball, 1RM= 1 Repetition Maximum, CM= Counter Movement, SP= Shoulder Press, SB= Swiss Ball, Score= Observational Study score format (max. 10)

Discussion

Core Stability Training

Just as 'core stability' is a heterogeneous term, so is 'core training'. Core training can be defined as 'processes that target muscular strengthening and motor control of the core musculature' (Nadler et al., 2002). It is challenging within all aspects of sports training to maximize training transfer to performance. CST is no exception.

There is a wide range of approaches towards core training, e.g. contraction exercises, proprioceptive training, balance training and sport-specific skill training. Reviewed study interventions range from Sling Exercise Training (SET) and unstable underground conditions to neuromuscular training. Many traditional core stability programs incorporate the use of Swiss balls yet few studies examined the effectiveness of these interventions. Sato (Sato & Mokha, 2009) used Swiss ball exercises in a group of runners and saw a significant increase in the 5000m performance of the CST group versus the control group. Performance on the SEBT improved as well, although there was not a significant difference when compared to the control group. Interestingly, Filipa (Filipa et al., 2010) used the SEBT as a functional performance test and saw a significant better performance outcome on the SEBT in the CST group (**Table 2**). A possible explanation for the lack of a significant outcome in Sato's study can be that different core stability interventions were used. The Swiss ball exercises might not enhance the performance on the SEBT as much as the progressive exercise program conducted in the study of Filipa. Different demographic factors can also be significant contributing factors; type and level of sport, age and gender of the athletes may result in divergent outcomes. These differences in study characteristics illustrate that interpreting and comparing the results of different studies is difficult.

In the analysed studies, almost no testing has been performed on elite level athletes. Most performance measures were performed on college and/or competitive level. After a 6-week SET intervention, Saeterbakken (Saeterbakken et al., 2011) reported a 4.9% increase in maximum throwing velocity in female handball players. Outcome measurement was performed using the simplest handball throwing technique. On a recreational level, this enhanced performance might be negligible. On the elite level, where inter-individual differences in athlete skills and performance are reduced to a minimum, this can be the difference between a point scored and a pass successfully delivered. These results can therefore not be used to determine whether core stability enhances performance in elite level athletes.

Core Stability & Performance Tests

As previously mentioned, there is no consensus about core stability and core stability training. Therefore there is also no consensus about which core stability test is the most validated. The included studies used a range of different tests. Sharrock (Sharrock et al., 2011) used the Double Leg Lowering Test to measure core stability and correlated it with different functional performance tests. Apart from the Medicine Ball Throw (MBT) he found no significant correlations other than the observation that male participants performed better on this test. Tse *et al* and Nesser *et al* both used the McGill core stability protocol (McGill, 2001) to assess core stability. The McGill protocol consists of four tests (back extensor test, abdominal fatigue test and side bridges) that emphasize core endurance. After an 8-week intervention that progressed from static to dynamic exercises, Tse

et al. (Tse et al., 2005) found no significant differences in both the McGill procedure and the performance tests when compared to the control group.

Nesser *et al* (Nesser et al., 2008) examined the relationship between scores on the McGill protocol and conventional performance tests. The results were significant but weak and inconsistent between the power clean, body weight jump and core. Other test scores showed no relationship. This study demonstrates that a 'one test fits all' method is not feasible.

The McGill protocol tests static core endurance whereas the intervention performed by Tse *et al.* quickly progressed to dynamic exercises. Nesser's performance tests consisted of One Repetition Maximum (1RM) tests and sprints that are all performed dynamically and in less than ten seconds. Therefore, the McGill protocol is not a suitable test for the goals described in these studies.

Keogh (Keogh et al., 2010) also evaluated core stability with a core endurance assessment and consecutively examined whether these measures could distinguish 1RM shoulder press (SP) performance in stable and unstable conditions. No significant between-group differences were found. Again, an endurance test was compared with a performance test which can be performed in less than 10 seconds. The findings of the studies mentioned above suggest that a weak correlation exists between results on conventional performance tests and static core stability. The use of a static core stability test has little functionality when used to examine the athletes' ability in dynamic performance test conditions. Tse *et al* reported no change in McGill test measurements and performance tests including a 2000m rowing ergometer (REM) test. This is remarkable since both the trial and control group continued their regular training schedules. These training schedules normally enhance performance on the 2000m REM test, so an improvement on this test was expected in both groups regardless of a core stability intervention.

Tse *et al* explains this by commenting the rowers were highly demotivated due to less-than-desired results in their competition and it is not unlikely that this demotivation impacted their performance on the 2000m REM.

Shinkle (Shinkle et al., 2012) examined the relationship between dynamic core strength and athletic function. Independent variables of core strength through various MBT's were used as measurements. The throw resembles the actions in the conventional performance measurements by transferring momentum created by lower extremities through the core to the upper extremities. These actions closely resemble the definitions of core stability as described by Bergmark and Kibler. By developing a dynamic core test, Shinkle found a significant relationship between dynamic core stability and performance tests in Division 1 college football players.

Saeterbakken, Sato and Filipa reported a significant increase in athletic performance after training core stability. They measured, and trained with sports-specific tests and interventions. The type of sports they examined all comprise of many dynamic movements. When trained and tested accordingly, core stability enhanced athletic performance.

Sport specificity

Traditional core stability training and measurements mainly put athletes in static non-functional positions. Articles that used the McGill testing protocol to investigate a correlation between conventional performance tests and core stability found no significant results. Articles that incorporated a more dynamic core testing protocol found a significant relationship between conventional performance tests and core stability. This suggests that dynamic performance requires dynamic core stability tests. RCTs that measured performance after a core stability intervention program with sport specific tests (Saeterbakken: maximum throwing velocity in handball, Sato: 5000m run time with runners) showed significant performance enhancements.

Limitations

In this review PubMed and The Cochrane Library databases were searched. These are mainly medical databases and in retrospect an additional search in databases like Sport Disc and CINAHL could have yielded more related articles. This can distort the results and further research should include other databases to gather more articles for reviewing. CINAHL does have a lower citation count (3.2 million compared to 22+ million in PubMed) and therefore the larger data base was chosen.

Recommendations for Future Research & Conclusions

Core stability has been theorized as a necessary aspect of training in the rehabilitation and performance sector. Core stability is suggested not only to prevent injuries, but also to enhance athletic performance. This review shows mixed results for the relationship between core stability and athletic performance. This may be due to the lack of consensus on the definition of core stability and the various tests used for core stability measurement, along with the many ways to approach the training of the core. However, studies that incorporated dynamic sport specific tests do show promise that core stability has a significant relationship with athletic performance. There currently is no test that evaluates core stability in athletes effectively. Static core stability tests are not specific to most sports and therefore should be used in restricted situations. Future research should consist of development of dynamic, sport specific tests and interventions.

Most sports require specific dynamic tasks of the body. Momentum from one extremity is transferred to the other through the core. Once basic control of the core is obtained, core stability should be trained and tested accordingly for optimal performance.

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Appendix 1: PEDro Scale

PEDro scale

1. eligibility criteria were specified	no ☐ yes ☐
2. subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	no ☐ yes ☐
3. allocation was concealed	no ☐ yes ☐
4. the groups were similar at baseline regarding the most important prognostic indicators	no ☐ yes ☐
5. there was blinding of all subjects	no ☐ yes ☐
6. there was blinding of all therapists who administered the therapy	no ☐ yes ☐
7. there was blinding of all assessors who measured at least one key outcome	no ☐ yes ☐
8. measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	no ☐ yes ☐
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	no ☐ yes ☐
10. the results of between-group statistical comparisons are reported for at least one key outcome	no ☐ yes ☐
11. the study provides both point measures and measures of variability for at least one key outcome	no ☐ yes ☐

Appendix 2: Observational Study Scale

1 point awarded for every criteria the study meets. The highest score is 10.
A study can be regarded as 'good quality' when it scores ≥ 6 .

1. Clear case/control definition	No ☐	Yes ☐
2. Description of accurate and appropriate outcome measures in all participants	No ☐	Yes ☐
3. Appropriate statistical tests used	No ☐	Yes ☐
4. Outcomes clearly described	No ☐	Yes ☐
5. Potential confounders clearly described	No ☐	Yes ☐
6. Participant characteristics described	No ☐	Yes ☐
7. Participants representative of population	No ☐	Yes ☐
8. Case/controls recruited from same population	No ☐	Yes ☐
9. Numerical description of important outcomes given	No ☐	Yes ☐
10. Recruitment of case/control over same time frame	No ☐	Yes ☐

