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Summary

Background: Although optimizing core stability is theorized to reduce injury risk for the spine and extremities, there is currently little evidence supporting if any core stability tests predict trunk injuries. The purpose of this study was to assess if biomechanical variables attained from core stability testing could be used to identify athletes who will later sustain a trunk injury.
Methods: 496 healthy Division I athletes (158 females) were tested at one of 2 testing sessions. Core stability testing consisted of a blindfolded single arm plank, performed on a force plate system, with commercially available software. Subjects performed two, 20 second trials for each upper extremity. Center of pressure data was quantified by velocity and frequency of motion and converted to T score. Injuries were considered for the study if they occurred no more than 180 days after testing, were non-traumatic in nature, and affected the lumbar spine, abdominal, or thoracic spine structures. 18 trunk injuries were identified. Data was averaged across the trials for each extremity. Mann-Whitney U was used to assess if differences existed between groups. Binary logistic regression was used to see if the force plate variables could be used to predict injury. P was set to 0.10.
Results: Mean T scores (SDs) for the uninjured group were 43.7(10.6) and 43.5 (10.7) for left/right, respectively; for the injured group, 36.9(8.7) and 40.7(7.3), respectively. Mann Whitney U showed significant differences between the trunk injury and healthy groups for both the left and right side ($P< 0.01$ and $P = 0.07$). Both extremity variables, when entered into the regression equation, show the ability to predict injury ($\chi^2 = 10.8$; $P< 0.01$).
Conclusion: Athletes who later sustained a trunk injury demonstrated poorer core stability versus the uninjured cohort. The injured group also had greater asymmetry in core stability measures when compared to the uninjured group.

ORIGINAL PAPER

Prediction of Trunk Injuries from Core Stability Testing in Collegiate Athletes

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Introduction

Trunk and lumbar spine injuries in collegiate athletes are relatively common. A recent 5-season epidemiological study of NCAA varsity athletes reported lumbar spine injury rates of 6.0 per 1000 athlete-exposures (AEs). The highest prevalence was in football players, who experience 24.6 lumbar spine injuries per 1000 AEs [4]. Women's gymnastics and tennis had the highest rates of injuries in female athletes [4]. The majority of these injuries were noncontact, and most injuries resulted in less than 24 hours of time loss from practice. Prior studies have found adolescent low back pain (LBP) to have a prevalence of 14%, a 1 year prevalence of 57%, and a lifetime prevalence of 66% [13].
Core stability is often theorized to improve performance and reduce injury risk for both the spine and the extremities. To date, no current screens have been validated for detecting trunk injuries. Popular injury screening tools (such as the Functional Movement Screen) have not been found to be reliable for injury prediction [3,9,16]. Other authors have highlighted the difficulties of developing effective injury screening tools and postulate that these may be nearly impossible to create [2,15,17].
There exist a variety of clinical tests designed to detect LBP injury risk. McGill (1999) defined a battery of four "core endurance" tests (flexor endurance, left side plank, right side plank and extensor endurance) to be a reliable method of assessment for core muscle endurance [8]. Further studies have found significantly decreased endurance times on these measures in athletes with a current episode of low back pain compared to healthy controls [1,8,17,18]. However, no studies to date have evaluated whether baseline scores on these tests are predictive of lumbar spine or trunk injuries. Additionally, even the healthy controls studied by Abdelraouf (2016) demonstrated "core endurance" times significantly less than McGill's previously established normative values [1]. Wilkerson (2015) discovered that high exposure to game conditions was the dominant injury risk factor for collegiate football players [19]. Additionally, he found that deficits in core muscle endurance or a mild degree of low back dysfunction, as assessed by the Oswestry Disability Index, increases

Keywords
Injury prediction – Core stability – Biomechanics – Collegiate athletes

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Vorhersehbarkeit von Rumpfverletzungen mithilfe von Rumpfstabilitätstests bei Hochschul-Athleten

Zusammenfassung

Hintergrund: Eine optimierte Rumpfstabilität reduziert das Verletzungsrisiko an Wirbelsäule und Extremitäten. Für diese Theorie sowie die Vorhersehbarkeit von Rumpfverletzungen auf der Basis von Rumpfstabilitätstests existieren aktuell nur wenige unterstützende Belege. Ziel dieser Studie war die Beurteilung, ob in Rumpfstabilitätstests erhobene biomechanische Variablen Hinweise darauf liefern könnten, welche Athleten sich in der Zukunft eine Rumpfverletzung zuziehen würden.
Methoden: 496 gesunde A-Kader-Athleten (158 weiblich) wurden bei einer von 2 Testsitzungen getestet. Die Überprüfung der Rumpfstabilität beinhaltete eine verblindete Übung mit einarmigem Unterarmstütz, der auf einem Kraftmessplattensystem mit handelsüblicher Software durchgeführt wurde. Die Studienteilnehmer führten für jede obere Extremität 2 Übungen zu je 20 Sekunden aus. Druckpunktdaten wurden mittels Geschwindigkeit und Bewegungsfrequenz quantifiziert und in den T-Score umgewandelt. Nicht-traumatische Verletzungen mit Auswirkung auf die Strukturen der Lenden- oder Brustwirbelsäule, die nicht mehr als 180 Tage nach dem Test auftraten, wurden in die Studienauswertung einbezogen. 18 Rumpfverletzungen wurden identifiziert. Die Daten wurden über die jeweiligen Übungen für jede Extremität gemittelt. Unterschiede zwischen den Gruppen wurden mithilfe des Mann-Whitney-U-Tests ermittelt. Durch binär logistische Regression wurde festgestellt, ob die an der Kraftmessplatte erhobenen Daten zur Vorhersage von

lumbar injury risk over the course of a season [19]. Leetun (2004) showed that Division I athletes who sustained an in-season lumbar spine or lower extremity injury presented with decreased core stability measures (tested preseason) versus an uninjured cohort [6]. The groups differed in peak isometric hip abduction, hip extension, and sustained side bridge measures; however, hip external rotation strength was the only predictor of injury (OR = 0.86). Additionally, only cross country runners and basketball athletes were included in this study [6].
The previously mentioned clinical tests focus on the muscle capacity and force generation aspects of core stability. The use of clinical core tests which have been validated to assess different facets of core stability (muscle capacity and neuromuscular control) have not been investigated to predict injury. Additionally, no studies to date have investigated trunk injury prediction in athletes participating in wide variety of sports, or injury prediction for abdominal and thoracic injuries in athletes.
Biomechanical testing using force plates are increasing in popularity and show promise in predicting both lower extremity injuries and upper extremity injuries in athletes [5,7,12]. To date, force plate technology has not been used to investigate its potential ability to predict trunk injuries in competitive athletes. The purpose of this study was to assess if variables attained from core stability testing using force plate technology could be used to identify collegiate athletes who will later sustain a trunk injury.

Methods

Approval was obtained from our institution's institutional review board. None of the authors have any conflicts of interest to report. All data was collected using a force plate (Kistler Inc; Amherst, NY, USA) system connected to a dedicated computer with commercially available software (Sparta Science). A video monitor was connected to the computer which displayed force plate center of pressure (COP) movement in real time. Force plate data were collected at 1000 Hz.
496 healthy Division I athletes were tested at one of 2 testing sessions (158 females). Subjects were instructed to stay as still as possible while maintaining a full plank position with one upper extremity on the force plate and the contralateral upper extremity behind their back (Figure 1).
The athlete was instructed to maintain their balance with as little movement as possible. Two, 20 second trials were performed for each extremity with a 15 second break between trials. The subjects were blindfolded during testing to eliminate the visual component of balance. Center of pressure data was quantified by velocity and frequency of motion.
Injuries were considered for the study if they occurred no more than 180 days after testing, were non-traumatic in nature, and affected the lumbar spine, abdominal, or thoracic spine structures. Diagnoses were as follows: lumbar sprain/strain (13); lumbar stress fracture (1); lumbar disc injury (3); thoracic sprain/strain (1); rib pain (1). Injury distribution by sport is listed in Table 1.

Statistical Methods

All data was analyzed using SPSS statistical package version 25 (SPSS Inc, Chicago, IL).
Data was converted to T score, with a higher T score indicating better

Verletzungen genutzt werden konnten. P wurde bei 0,10 festgesetzt.
Ergebnisse: Die mittleren T-Scores (Standardabweichung, SD) lagen in der Gruppe ohne Verletzung bei 43.7 (10.6) und 43.5 (10.7) jeweils für rechts und links, sowie bei 36.9 (8.7) und 40.7 (7.3) in der Gruppe mit Verletzungen. Der Mann-Whitney-U-Test zeigte sowohl für die linke als auch die rechte Seite signifikante Differenzen zwischen der gesunden Gruppe und der Gruppe mit Rumpfverletzungen ($P < 0.01$ und $P = 0.07$). Nach Eingabe in die Regressionsgleichung wiesen beide Extremitätenvariablen die Fähigkeit zur Vorhersage von Verletzungen auf ($x2 = 10.8$; $P < 0.01$).
Fazit: Diejenigen Athleten, die sich später eine Rumpfverletzung zuzogen, hatten schlechtere Rumpfstabilitätswerte erreicht als die Gruppe ohne Verletzung. Die Gruppe mit Verletzungen hatte zudem im Vergleich zur Gruppe ohne Verletzung eine größere Asymmetrie der Rumpfstabilitätswerte aufgewiesen.

Schlüsselwörter
Vorhersehbarkeit von Verletzungen – Rumpfstabilität – Biomechanik – Hochschulathleten

Figure 1
Test Position for measurement of single arm plank.

stability (decreased sway). Each side (left, right) was averaged across the 2 trials for each subject. T-tests were used to determine if differences existed between sides (left versus right) for both the injured and the uninjured groups. 18 trunk injuries were identified. Mann-Whitney U was used to assess if differences existed between groups. Binary logistic regression was used to see if the force plate variables could be used to predict injury. *P* was set to 0.10. A more liberal *P* was initially selected as this study is exploratory in nature.

Results

Table 2 displays the means and standard deviations for the plank T-scores for left and right sides for the injured and uninjured groups. Mann Whitney U showed significant differences between the trunk injury and healthy groups for both the

Table 1. Injury Distribution by sport.

Women's Injuries by Sport	Basketball (1); field hockey (1); rowing (2); squash (1); swimming (2); tennis (2); volleyball (3)
Men's Injuries by Sport	American football (2); lacrosse (1); track & field (2); wrestling (1)

Table 2. Means (SDs) of Core Stability T-scores and Difference between Sides.

	Left Mean (SD)	Right Mean (SD)	Difference Between L/R Sides
Uninjured	43.7 (10.6)	43.5 (10.7)	T = 0.30, df = 950, P = 0.76
Injured	36.9(8.7)	40.7(7.3)	T = 1.41, df = 34, P = 0.16

left and right side ($P< 0.01$and $P = 0.07$, respectively). Both extremity variables, when entered into the regression equation, show the ability to predict injury ($\chi^2 = 10.8$; $P< 0.01$).

Discussion

Our study is to first to show the relationship between poor performance on a core stability test and trunk injury in a collegiate athlete population. We showed that athletes participating in a variety of varsity sports who had lower scores on a single arm plank test were more likely to sustain a trunk (lumbar spine, thoracic spine, or abdominal) injury. The single arm plank position was used for several reasons. First of all, this test can be administered both clinically, but also easily using a force plate system. This position has been validated to challenge both muscle capacity and neuromuscular control facets of core stability [10]. This test is also adequately challenging for an athletic population. Lastly, studies have established muscle activity levels in all muscles in the upper quarter [11]; thus, it is known that the upper quarter musculature and trunk musculature are both involved in test performance.

The visual component of balance/stability was eliminated by blindfolding the athletes during the testing procedure. This resulted in a test that was more challenging for the athletes, and also was resultant in the athletes relying entirely on other systems (muscle capacity, neuromuscular control, and vestibular systems) for successful task completion. Previous literature in the lower extremity and trunk have noted that the removal of visual input results in decreased test performance, thereby making the test more challenging [14].

While previous studies showed impaired measures of core stability or hip strength in athletes with a current episode of low back pain [1], to date, none have shown predictive validity. Therefore, it is possible that some of the subjects demonstrated impaired performance secondary to pain, and not true impaired strength or stability. Examining these measures from a prospective perspective is warranted in the future.

The injured group also appeared to have greater asymmetry than the injured group, exhibited by a trend toward significance when comparing left to right side. Cohen's *d* was 0.47, indicating a medium effect size. This effect size indicates that with a larger sample size, we would be likely to see a difference.

One of the limitations of this study was that biomechanical variables were used; thus, we do not know if clinical variables for the same test could identify at-risk athletes. Further, if clinical variables could identify at-risk athletes, it is unknown whether a specific cut off score would be predictive of injury. Future directions should examine the utility of a clinical version of this test. Additionally, future directions should include intervention efficacy after identification of at-risk athletes to develop a comprehensive injury prevention program.

Conclusion

Athletes who later sustained an abdominal, thoracic spine, or lumbar spine injury demonstrated poorer stability when compared to the uninjured cohort.

Conflict of Interest

There is no conflict of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.orthtr.2021.08.007.

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