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ORIGINAL RESEARCH

THE RELATIONSHIP BETWEEN TRUNK ENDURANCE PLANK TESTS AND ATHLETIC PERFORMANCE TESTS IN ADOLESCENT SOCCER PLAYERS

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ABSTRACT

Background: Although it is believed that trunk function is important for athletic performance, few researchers have demonstrated a significant relationship between the trunk function and athletic performance. Recently, the prone plank and side plank tests have been used to assess trunk function.

Purpose: The purpose of this study was to investigate the relationships between trunk endurance plank tests and athletic performance tests, including whether there is a relationship between long distance running and trunk endurance plank tests in adolescent male soccer players.

Study design: Cross sectional study design.

Methods: Fifty-five adolescent male soccer players performed prone and side plank tests and seven performance tests: the Cooper test, the Yo-Yo intermittent recovery test, the step 50 agility test, a 30-m sprint test, a vertical countermovement jump, a standing five-step jump, and a rebound jump. The relationships between each individual plank test, the combined score of both plank tests, and performance tests were analyzed using the Pearson correlation coefficient.

Results: The combined score of plank tests was highly correlated with the Yo-Yo intermittent recovery test ($r = 0.710$, $p < 0.001$), and was moderately correlated with the Cooper test ($r = 0.567$, $p < 0.001$). Poor correlation was observed between the prone plank test and step 50 agility test ($r = -0.436$, $p = 0.001$) and no significant correlations were observed between plank tests and jump performance tests.

Conclusions: The results suggest that trunk endurance plank tests are positively correlated with the Yo-Yo intermittent recovery test, the Cooper test, and the step 50 agility test.

Level of Evidence: Level 2

Keywords: Agility, core strength, jump, long distance running, prone plank

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INTRODUCTION

The trunk plays an important role in the transfer of energy and the connection of movements between the lower and upper extremities.[1-4] There are many muscles within the trunk and optimal activity of these muscles is required to adjust the movement and posture of the trunk during sports activities.[4] Thus, many athletes, including professional, amateur, and adolescent sports players perform various types of trunk exercises. In previous studies, researchers have reported that trunk exercises improve athletic performance in athletes.[5-7]

It is important to assess trunk function as a part of an athlete's fitness level. Trunk function is often defined as trunk or core stability, which includes the coordination, strength, and endurance of trunk muscles. However, appropriate methods for assessing trunk function are not agreed upon. Trunk muscular endurance tests, which measure the holding time of a specific posture, are often utilized as assessment tools of trunk function.[8-15] McGill's core endurance tests, comprised of the trunk flexor test, extensor test, and lateral plank test, are often used to assess trunk muscle endurance.[8-14] However, there have been few published studies that have assessed the relationships between trunk endurance tests and athletic performance tests.[12,13,15] Although Nesser et al[12] demonstrated weak or moderate correlations between McGill's tests and athletic performance tests including sprint, jump, and agility tests in male collegiate football players, no significant correlations were found in female collegiate soccer players in another previous study.[13] Sharrock et al[15] also reported that no correlation existed between the leg lowering test, which is one of the standard trunk endurance tests, and performance tests in male and female collegiate athletes. Consequently, the relationship between trunk endurance tests and athletic performance tests remains unclear.

In recent research, the prone plank test has been used to assess trunk flexor endurance.[8,16-18] Although biomechanical differences between the prone plank test and McGill's trunk flexor test have been reported,[17,18] the relationships between the prone plank endurance test and athletic performance tests were not investigated. Most researchers previously investigated athletic performance test relationships using McGill's tests for college athletes, and have adopted jump, sprint, and agility tests as performance tests. However, the relationship between endurance plank tests and performance tests is not known and there has been no study that investigates the relationship in adolescent athletes specifically.

Therefore, the purpose of this study was to investigate the relationships between trunk endurance plank tests and athletic performance tests in adolescent soccer players. Because trunk endurance tests can assess muscular endurance, a hypothesis was that trunk endurance plank tests would be associated with running endurance performance.

METHODS

Participants

Fifty-five male high school soccer players (age 16.3±0.5 years; height 172.6±5.9 cm; weight 61.9±5.7 kg) participated in this study. They were members of the same high school soccer club and were participating in soccer practices and games six times per week at the time of the investigation. Before the study, participants were interviewed about current injuries, pain, and history of injuries; they were excluded if they had any lower back pain or lower or upper extremity injuries that required treatment or which might have inhibited performance within the prior three months. The experimental protocol was explained to all participants and their parents both verbally and in written form, and their informed consent was obtained. The present study was reviewed and approved by the Institutional Ethical Committee at the University of Tsukuba, and carried out in accordance with the Declaration of Helsinki.

Procedures

Two trunk endurance tests and seven measures of athletic performance measurements were performed. For assessing the function of the trunk, two trunk endurance tests, the prone plank and side plank tests, were performed. Athletic performance measurements included the Cooper test, the Yo-Yo intermittent recovery test (YYIRT), a 30-m sprint test, the step 50 agility test, a vertical countermovement jump (CMJ), the standing five-step jump (SFSJ), and a rebound jump (RJ) for assessing endurance, intermittent endurance, sprint, agility, and jumping abili-

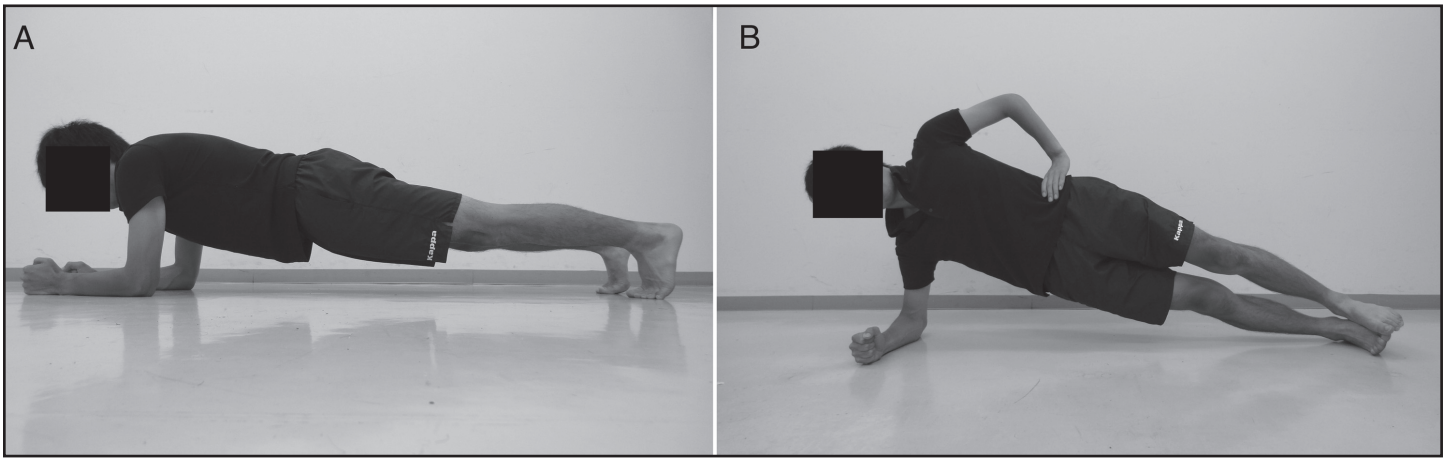

Figure 1. *Trunk endurance plank tests: (A) prone plank test and (B) side plank test.*

ties. These measurements were conducted on two separate days. On the first day, the 30-m sprint test, CMJ, RJ, and YYIRT were performed. On the second day, the trunk endurance plank tests, the SFSJ, the step 50 agility test, and the Cooper test were conducted. The YYIRT and Cooper tests were performed at the end of all measurements in order to avoid fatigue, while the other tests were performed in random order. The measurements of each day were performed after a 10-minute warm-up, which consisted of jogging, dynamic stretching, sprinting, and jumping.

Measurements

For the prone plank test, participants maintained a prone position in which the body weight was supported by the toes and forearms (Figure 1A).[16] The side plank test was performed with the participant lying on their side, supported by the foot and elbow (Figure 1B). The side plank test was performed on both sides. Participants were instructed to maintain a neutral position of the spine and pelvis, and to breathe normally during testing. Each test was terminated when the participant was unable to maintain their posture or their pelvis moved up or down five or more cm. Each holding time was recorded using a stopwatch. The holding time of the prone plank test, right and left side plank tests, and the combined score of all plank tests were used for analyses.

The Cooper test was adopted as a continuous long distance running test. Participants ran on an outdoor track for 12 minutes. Participants were instructed to run as many laps as possible during these 12 minutes. The examiner counted the laps completed during the 12-minute test period, while calling out the elapsed time at 3, 6, 9, and 12 minutes. A measuring wheel was used to determine the fraction of the last lap completed by each participant. The total distance was reported in meters using the distance run during the number of full laps completed and the measurement of the last partial lap.

The YYIRT was performed to assess the ability to repeatedly perform high-intensity exercise.[19] The present study adopted the YYIRT Level 2 test which consisted of two repeated 20-m runs at a progressively increasing speeds controlled by audio beeps from a tape recorder. Between each run bout the participants had a 10s rest period. When the participant failed to reach the finish line in time twice, the distance covered was recorded and represented the test result.[20]

The 30-m sprint test was used as a measurement of speed. The sprint time for 30-m was measured using a photocell timing system (Speedtrap; Fitness Apollo Japan, Co., Ltd., Tokyo, Japan) positioned at the starting and finishing lines at a height of 1m. Participants started from a standing position, placing their forward foot 0.5m behind the sensor. Runners attempted the 30-m sprint twice. The faster time was selected for analysis.

The step 50 agility test is comprised of 50-m of running, including a change of direction and various steps, such as the crossover step and back-pedaling (Figure 2). The marker location to perform testing was arranged as published in a previous study.[5] The

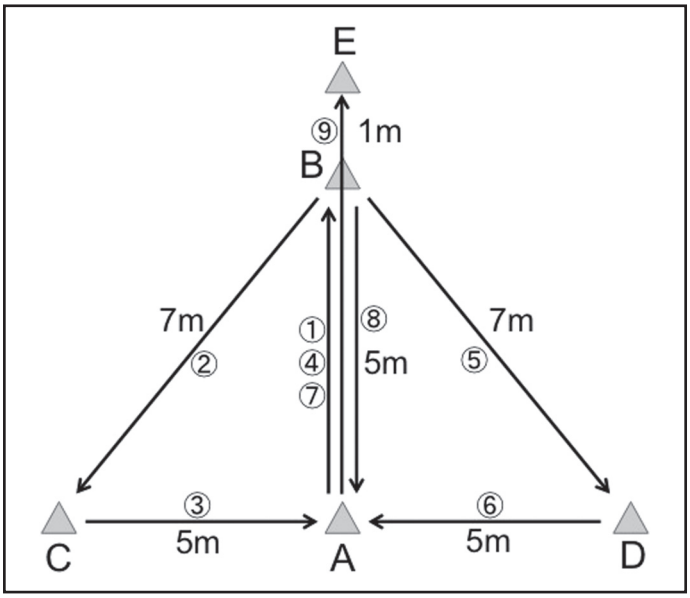

Figure 2. *The layout and order of the Step 50 agility test: Participant starts at A, and sprints to B. They next go to A around C with a crossover step. Another sprint is towards B again, then go to A around D using a crossover step. From A, they sprint to B one more time, then back to A by back pedaling. A final sprint to E ends one set. The numbers beside arrows indicate the order of performance.*

time of the step 50 agility test was measured from the signal of the start to the passing of the goal gate using the photocell timing system positioned on both sides of the goal line at a height of 1m. Each participant performed the test twice, with a minimum three-minute rest between trials in order to avoid fatigue. The faster time was selected for analysis.

For the SFSJ, participants began the first jump from a two-legged from a standing position with feet shoulder-width apart. Then, they did 4 jumps onto a single leg, alternately, following the one-legged landing after first jump. The final landing following the fifth jump was performed with two legs. The distance from the start line to the heel of the final landing was recorded using a measuring tape. The participants performed the test twice, and the greater distance was selected for analysis.

The CMJ with arm swing was performed on a contact mat (DKH Inc., Tokyo, Japan) and jump height was calculated from the flight time using the following equation:[5,21]

$$\text{Jump height} = (g \times \text{flight time}^2)8^{-1}$$

In this equation, g denotes the acceleration of gravity (9.81 m/s^2). The CMJ testing was performed twice, and the higher jump height was selected for analysis.

The RJ was used to assess ability of explosive power produced over repetitive jumps. This test is related to quick movements with a short ground contact time. Participants performed the RJ, which required them to repeat the vertical jump six times, using a countermovement arm swing while on the mat switch (Multi Jump Tester; DKH Inc., Tokyo, Japan). Participants were instructed to shorten contact time to the greatest extent possible and to jump as high as possible. The RJ index was calculated on the basis of jump height and contact time (jumping height / contact time).[5,21] The measurement of the RJ was performed twice. The higher RJ index was selected for analysis.

Statistical analysis

All statistical analyses were performed using the SPSS 19 software (SPSS for Mac version 19; SPSS Inc. Chicago, USA). The Pearson correlation coefficient was used to determine the relationships between trunk endurance plank tests and athletic performance tests. Statistical significant was set at $p < 0.05$. The magnitude of correlation (r) was rated as follows: little ($0.00 < |r| < 0.25$), low ($0.26 < |r| < 0.49$), moderate ($0.50 < |r| < 0.69$), high ($0.70 < |r| < 0.89$), and very high ($|r| > 0.90$).[22]

RESULTS

Performance variables are listed in Table 1. The correlations between the trunk endurance plank tests and athletic performance tests are presented Table 2. High correlations were observed between the combined score of plank tests and the YYIRT ($r = 0.710$, $p < 0.001$) (Figure 3). Further, the combined score of plank tests provided a moderate correlation with the Cooper test ($r = 0.567$, $p < 0.001$) (Figure 4) and low correlation with the step 50 agility test ($r = -365$, $p = 0.006$). Moderate and low correlations were observed between the prone plank test and YYIRT ($r = 0.602$, $p < 0.001$), Cooper test ($r = 0.434$, $p = 0.001$), and step 50 agility test ($r = -436$, $p = 0.001$). The right side plank test correlated moderately to the YYIRT ($r = 0.590$, $p < 0.001$) and Cooper test ($r = 0.514$, $p < 0.001$).

Table 1. *The variables of trunk endurance plank tests and athletic performance tests.*

Trunk endurance plank tests	
Prone plank test (s)	124.0 ± 48.8
Right side plank test (s)	87.0 ± 25.8
Left side plank test (s)	92.6 ± 23.0
Combined score (s)	303.6 ± 79.5
Athletic performance tests	
YYIRT (m)	591.3 ± 228.8
Cooper test (m)	3245.8 ± 132.9
SFSJ (m)	11.03 ± 0.74
Step 50 (s)	15.91 ± 0.49
RJ-index	1.772 ± 0.416
Sprint (s)	4.69 ± 0.22
CMJ (cm)	37.82 ± 4.77

CMJ, vertical countermovement jump; RJ, rebound jump; SFSJ, standing five-step jump; YYIRT, Yo-Yo intermittent recovery test.

Table 2. *Correlations between trunk endurance plank tests and athletic performance tests.*

	YYIRT	Cooper	SFSJ	Step 50	RJ index	Sprint	CMJ
Prone plank test	.602**	.434**	.124	-.436**	.169	-.273*	.172
Right side plank test	.590**	.514**	.152	-.222	.244	-.242	.125
Left side plank test	.515**	.464**	-.023	-.088	.166	-.135	-.043
Combined score	.710**	.567**	.119	-.365**	.231	-.285*	.133

* Significant correlation ($p<0.05$)

** Significant correlation ($p<0.01$)

CMJ, Vertical countermovement jump; RJ, Rebound jump; SFSJ, Standing five-step jump; YYIRT, Yo-Yo intermittent recovery test.

DISCUSSION

The present study investigated the relationships between trunk endurance plank tests and athletic performance tests. The main finding was that the combined score of plank tests showed a high correlation with the YYIRT, which requires repeated sprint performance including change of direction. Although there have been several studies regard-

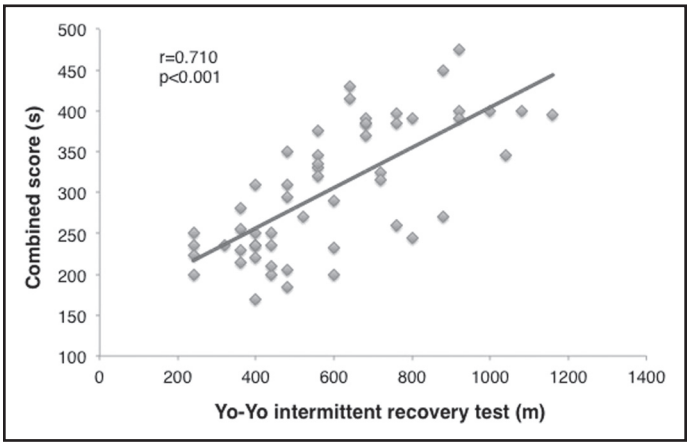

Figure 3. *The relationship between the combined score of plank tests and Yo-Yo intermittent recovery test.*

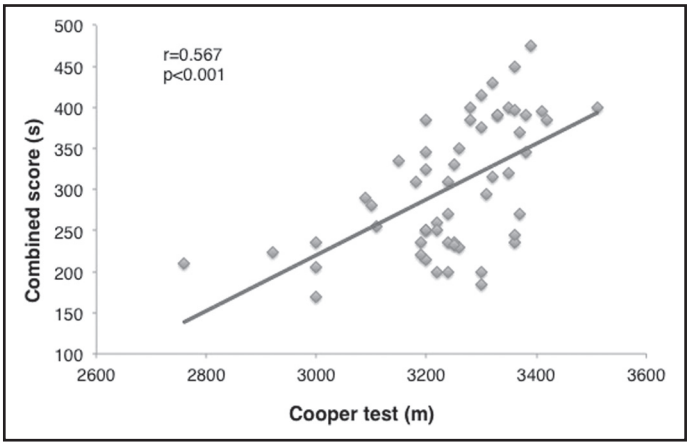

Figure 4. *The relationship between the combined score of plank tests and Cooper test.*

ing the relationships between the trunk endurance tests and athletic performance tests,[12-15] this is the first study to demonstrate high and moderate correlations between tests.

In the current study, significant correlations with the trunk endurance plank tests were in running performance tests, but not in jump performance tests. Notably, the YYIRT demonstrated a higher correlation than other running performance tests. The YYIRT requires sprinting and change of direction and can assess intermittent anaerobic endurance ability. In the current study, low and moderate correlations were found between the plank tests and sprint, agility, and the Cooper tests. Because the YYIRT measures several aspects of athletic abilities, this could explain it being highly correlated with the plank tests. Previous studies that have used other trunk flexor tests have not investigated the relationship between the trunk endurance test and running endurance tests.[12-15] The trunk endurance plank tests used in this study, as well as other trunk endurance tests, assess the trunk muscle endurance by requiring the subject to isometrically maintain the same posture for the duration of the test. Sasaki et al[23] have reported that change of direction performance correlated with the trunk angular displacement during the change of direction. Moreover, excessive motions of the trunk, particularly trunk rotation, interfere with the efficient transfer of energy during running-based sports activities.[4] Thus, the control of trunk movement is important for movement efficiency during running as well as change-of direction performance. In previous studies, it has been reported that trunk exercise programs, which were designed to enhance core stability or strength, improved the results of the Cooper test and the 5,000m time trial.[5,7] The current study demonstrated a moderate correlation between combined trunk plank test scores and the Cooper test. These results indicate that trunk plank tests may be related to running performance, and therefore may be useful tools for assessing abilities of athletes whose require intermittent and continual endurance performance and change of direction, such as soccer and basketball players. It should be noted, however, that a limitation of this study is that the tests were only conducted on adolescent male soccer players. These results may not be seen in female soccer players or athletes of other age groups.

In contrast, there were no significant correlations between trunk endurance plank tests and jump performance tests. Trunk function appears important for jump performance as many researchers have reported that a trunk exercise program enhanced the CMJ and RJ.[5-9] Although researchers have demonstrated a moderate correlation between McGill's tests and CMJ performance,[12] several other researchers have demonstrated no significant correlation between trunk endurance tests and CMJ performance.[13,15] The results of this study could not confirm the relationship between trunk muscular endurance and jump performance. Trunk abilities required for the trunk endurance tests and jump performance are different. Thus, trunk endurance tests, including the plank tests, may not appropriately assess trunk

function required for jumping performance. Each jumping act is performed explosively and rapidly. Consequently, coordination of trunk muscles and instantaneous control of the position and movements of the trunk during dynamic motion are required. Future research considering the other trunk function tests, including instantaneous trunk control, is needed to better understand this relationship.

CONCLUSION

The results of the current study demonstrated a high correlation between the combined score of trunk endurance plank tests and the YYIRT and a moderate correlation with the Cooper test. Moreover, the prone plank test showed moderate and low correlations with the YYIRT, Cooper test, the step 50 agility test, and the 30m sprint test. These results suggest that trunk plank tests may be able to utilize to assess trunk function of athletes whose activities require intermittent and continual endurance performance and change of direction, such as soccer players.

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