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EFFECTS OF SLING EXERCISE ON THE CORE ENDURANCE AND PERFORMANCE OF BASKETBALL PLAYERS

EFEITOS DO EXERCÍCIO COM SLING NA RESISTÊNCIA DO CORE E DESEMPENHO DE JOGADORES DE BASQUETEBOL

EFECTOS DEL EJERCICIO CON SLING EN LA RESISTENCIA DEL CORE Y RENDIMIENTO DE LOS JUGADORES DE BALONCESTO

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ABSTRACT

Introduction: Strong core stability and strength enable the trunk to transfer the maximum amount of torque to the terminal segments, which is conducive to improving athletic performance. Because sling training is a new core exercise method, its effect on trunk endurance relative to basketball performance has rarely been studied. Objective: To investigate whether a core exercise program in a specific sports group can improve core and sports-specific performance. Methods: A total of 40 college students majoring in basketball were randomly assigned to training and control groups. A standardized set of core endurance and basketball-specific performance tests were used to determine and assess the effects of sling training on trunk strength, endurance, and control. Results: Flexor, extensor, and right and left lateral trunk flexor muscles endurance were significantly greater in the training group than in the control group, and the time to complete the layup obstacle course was shorter than in the control group at the end of the training program, $p<0.01$. No differences between the two groups were found in the penalty shot, the fixed position shot, or the vertical jump and reach at the end of the training program. Conclusions: Sling exercises can improve the core endurance and strength of basketball players and increase the speed of lay-ups over obstructions. ***Level of evidence I; Randomized clinical trial.***

Keywords: Core Stability; Abdominal Core; Muscle strength; Endurance training; Athletic performance.

RESUMO

Introdução: A sólida estabilidade e a força do core permitem que o tronco transfira o torque máximo para os segmentos terminais, o que é propício para melhorar o desempenho atlético. Como um novo método de exercício para o core, o efeito do treinamento com sling na resistência do tronco com relação ao desempenho no basquete tem sido pouco estudado. Objetivo: Investigar se um programa de exercícios para o core em um grupo esportivo específico pode melhorar o desempenho do core e específico do esporte. Métodos: Um total de 40 estudantes universitários formados em basquete foram aleatoriamente designados para grupos de treinamento e controle. Uma série padronizada de testes de resistência do core e desempenho específico do basquete foi usada para determinar e avaliar os efeitos dos exercícios com sling na força, resistência e controle do tronco. Resultados: A resistência dos músculos flexores, extensores e flexores laterais direito e esquerdo do tronco foi significativamente maior no grupo treinamento em comparação ao grupo controle e o tempo para concluir o teste de bandeja com obstáculos foi menor que o do grupo controle no final do programa de treinamento, $p < 0,01$. Não houve diferenças entre os dois grupos quanto ao lance livre, arremesso em posição fixa e salto vertical e alcance no final do programa de treinamento. Conclusões: Os exercícios com sling podem melhorar a resistência e a força do core em jogadores de basquete e aumentar a velocidade das bandejas com drible. **Nível de evidência I; *Estudo clínico randomizado.***

Descritores: *Estabilidade Central; Centro Abdominal; Força muscular; Treinamento de resistência; Performance atlética.*

RESUMEN

Introducción: La sólida estabilidad y fuerza del core permiten que el tronco transfiera el torque máximo a los segmentos terminales, lo que conduce a mejorar el rendimiento deportivo. Como método novedoso de ejercicio para el core, se ha estudiado poco el efecto del entrenamiento con ejercicios con sling sobre la resistencia del tronco en relación con el rendimiento en el baloncesto. Objetivo: Investigar si un programa de ejercicios para el core en un grupo deportivo específico puede mejorar el rendimiento del core y específico del deporte. Métodos: Un total de 40 estudiantes universitarios con especialización en baloncesto fueron asignados aleatoriamente a grupos de entrenamiento y de control. Se utilizó una serie estandarizada de pruebas de resistencia del core y rendimiento específico del baloncesto para determinar y evaluar los efectos de los ejercicios con sling en la fuerza, la resistencia y el control del tronco. Resultados: La resistencia de los músculos flexores, extensores y flexores laterales derecho e izquierdo del tronco fue significativamente mayor en el grupo de entrenamiento en comparación con el grupo de control, y el

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tiempo para completar la prueba de tiro con obstáculos fue menor que el del grupo de control al final del programa de entrenamiento, p<0,01. No hubo diferencias entre los dos grupos en lo que respecta a: tiro libre, lanzamiento en posición fija y salto vertical y alcance al final del programa de entrenamiento. Conclusiones: Los ejercicios con sling pueden mejorar la resistencia y la fuerza del core en jugadores de baloncesto y aumentar la velocidad de los tiros con dribling. ***Nivel de evidencia I; Ensayo clínico aleatorizado.***

Descriptores: *Estabilidad Central; Núcleo Abdominal; Fuerza muscular; Entrenamiento de resistencia; Rendimiento atlético.*

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INTRODUCTION

Core exercises, which target trunk strength, are extensively used in rehabilitation and athletic training to prevent or treat sports injuries.[1–3] Several professionals have incorporated core exercises into practice; these exercises can prevent and treat lower back pain and injuries to the extremities, including knee injuries and hamstring strains.[4,5] Moreover, core exercises can condition core muscles and improve sports performance.[6–8]

Core-related exercises such as Swiss ball training, balance training, weight training, and yoga have become popular physical activities even among general populations in recent years. Sling exercise training (SET) has been recently emerged as a novel method of core exercise.[9] This approach uses of a dangling rope and auxiliary equipment to support body weight and provide graded resistance. The SET could maximizing the sense of balance and enhancing trunk stabilization compared with traditional treatments by stimulate more proprioceptors, nerve roots, motor organs of the cerebrum and reactivate the muscles.[10] Several studies further demonstrated the benefits of exercising with slings on sports performance.[11–13]

The types of muscles that are included in the core and are considered targets in treatment have been variably described. The core includes 29 pairs of muscles that surround the trunk and abdomen on all sides (front: abdominal muscles, back: paraspinal/erector spinae and gluteal, top: diaphragm, and bottom: pelvic floor and hip girdle).[14] The core musculature controls the balance between movement and stability. These muscles prevent movement of the spinal to provide a stable base for the limbs, and thus generate power or transfer load through the body.[15,16] These muscles also enable smooth and controlled movement for shock absorption, energy expenditure minimization, and body movements.[15] Balance depends on these assumed functions. Most sporting tasks aim to control the trunk to allow the maximum transfer of torque to the terminal segments. Thus, excess movements of the core through superior transfer of torque to the extremities, which significantly influence athletic performance, are prevented.

There are many studies promote core training programmes and exercises for performance enhancement without providing a strong scientific rationale of their effectiveness, especially in the sporting sector. A few studies[11–13,17–20] investigated the effect of core training on fast-discrete complex movements (shooting, serving, kicking and maximal golf club-head swing velocity), all observed positively effects on the performance. On the other hand, Both Gencer[21] and Stanton et al.[22] reported that no increased performance were observed in swimming or running after core training, respectively. The research on core training leads to inconsistent results, which may be due to different sports characteristics, different exercise methods and different test indicators and so on.

Clinical and practical measurement of core exercises is an issue in sports. Muscle activities, particularly for the deep muscles of the trunk, cannot be easily recorded outside the laboratory. Alternative testing protocols, including the method described by McGill,[3] have been developed to evaluate core endurance (i.e., maintaining trunk alignment when external force is applied) and core strength (i.e., simple repetition of resisted movement). We speculated that implementing a sling-based core exercise program on a specific sports group could improve core and sports-specific performance. This hypothesis was tested on a group of college basketball players by using the sling equipment CKT of a cable system, which has been developed with simplified pulleys and sling support.

METHODS

Recruitment

A total of 40 college students majoring in basketball (basketball training: 9.7 ± 3.2 years) from Shanghai University of Sport voluntarily participated in the study. The subjects were randomly categorized into training (n = 20) and control (n = 20) groups. Their average age, height, and weight were 22 ± 4 years, 184 ± 3 cm, and 74 ± 4 kg, respectively, in the training group, and 22 ± 3 years, 184 ± 8 cm, and 78 ± 11 kg, respectively, in the control group. Individuals who previously suffered from lower back pain, sustained injuries, or practiced sling exercises over the last six months were excluded from the study. This project was approved by the ethics committee of Shanghai University of Sport (approval code: 2017017), and all participants gave an informed written consent before testing.

Procedures

All the subjects routinely engaged in 1.5-hour basketball training sessions 3 times per week and in 1.5-hour resistance training sessions 2 times per week. Each resistance training session consisted of 4 sets of 6 exercises involving the upper limbs, trunk, and lower limb muscles using a load of 6–10 repetition maximum. An additional set of an 11-exercise training protocol with sling exercises was added to the training group (Figure 1 and Table 1). The baseline core endurance and strength were measured for all participants before the sling training according to methods below. The subjects in the training group performed the protocol twice a week for eight weeks in addition to their regular basketball practice. The control group only continued their usual basketball training and resistance training. Core endurance, strength, jumping-reaching altitude, and basketball-specific performance were measured before and after eight weeks of training program. Basketball-specific performance tests or measurements were conducted on the first day, and core endurance and strength tests or measurements were performed on the second day. These individuals were not required to perform warm-up exercises in order to limit muscle fatigue before the measurement.

Tests and data collection

Core strength test: Number of successful sit-ups completed in 60 s.
Core endurance tests: No warm-up exercise was performed before the test to prevent muscle fatigue. A five-minute rest was needed between the tests. A handheld stopwatch was used to measure the duration the participants maintained the test position.
Flexor endurance test (FET):[3] This test evaluated the performance of abdominal muscles. The participants lay in a supine position on a table in a hook-lying position. Their arms were folded across their chests, and

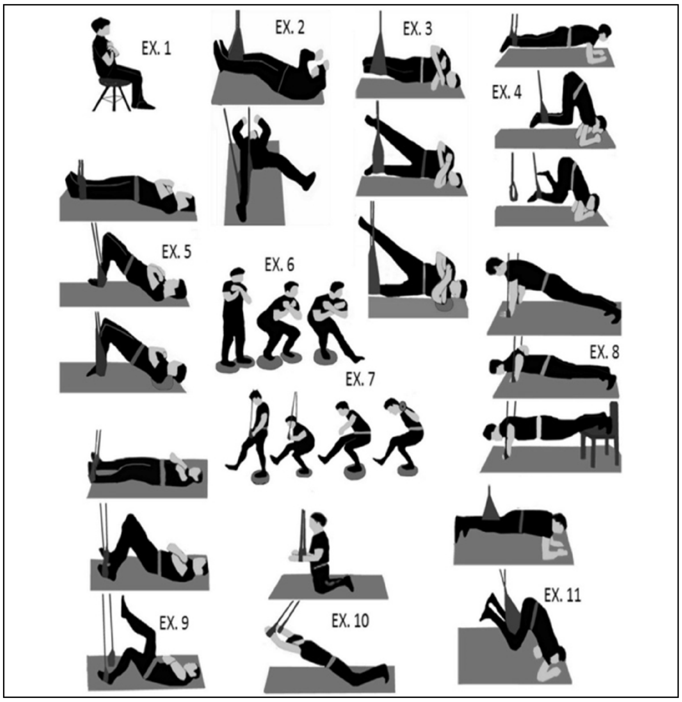

Figure1. Sketch of training protocol with sling exercise (see their descriptions in table 1). Ex. indicates exercise with Arabic number.

their backs were positioned against a support angle of 55° from the table. The examiner secured the toes of the participants, and the support was moved 10 cm from the back. The participants held the static unsupported position as long as possible. The test was terminated when the back of the participants touched the support jig.

Extensor endurance test (EET):[3] This test evaluated the lower back extensor muscles. The upper bodies of the participants were cantilevered over the end of a bench with their arms folded across the chest and their feet secured. This position was held until the upper body dropped below the horizontal position.

Lateral endurance test (LET):[3] This test evaluated the control of lateral abdominal muscles in the frontal plane. The participants supported their trunks on one elbow and foot, with their hips elevated off the floor. This position was maintained until the participants failed to sustain a straight-back posture.

Basketball-specific performance tests

The participants completed two random tests of basketball-specific performance after 20 min of warm-up (jogging around the basketball court), and practiced one to three trials before the test data were recorded. The test procedures included the following tests, and the mean of three repetitions was recorded and calculated.

Jumping and reaching altitude: Subjects with chalk on their right fingers employed a running approach before jumping as high as possible

Table 1. Core Training Protocol (Match to Figure 1).

Exercises (Ex.)	Exercises	Training period (Weeks)	Repetition (Sets x Min/repetitions)	Rest (Sec.) (Between Sets)
Ex. 1	The participant sits on a stool with hands and feet crossed and upper body kept upright. Holding time is increased as the intervention continued.	1,2 3,4 5,6 7,8	2 x 1min 2 x1min and 30s 2 x 3min 2 x 3min	120
Ex. 2	One leg is hung by slings, and the pelvis is lifted off the floor. The other leg performs adduction and abduction.	1,2 3,4 5,6 7,8	2 x 10 2 x 12 3 x 12 3 x 15	120
Ex. 3	The participant side-lied on the floor with both feet hung by slings. One leg is fixed, while the other performs adduction and abduction.	1,2 3,4 5,6 7,8	2 x 10 2 x 12 2 x 12 2 x 15	120
Ex. 4	The participant places both feet on the slings with knees bent. The difficulty is increased throughout the training period.	1,2 3,4 5,6 7,8	2 x 5 2 x 8 2 x 8 2 x 10	120
Ex. 5	Both feet are placed on the slings, and the pelvis is lifted away from the floor. The participant bends knees and then extends them. The difficulty is increased throughout the training period.	1,2 3,4 5,6 7,8	2 x 10 2 x 12 2 x 12 2 x 15	120
Ex. 6 1-4 week 5-8 week	The participant stands on the balance mat and performs squats. The difficulty is increased throughout the training period.	1,2 3,4 5,6 7,8	2 x 10 2 x 12 2 x 12 2 x 15	120
Ex. 7 1-4 week 5-6 week 7-8 week	The participant stands on one leg on the balance mat and performs squats, with slight help from the slings. The difficulty is increased throughout the training period.	1,2 3,4 5,6 7,8	2 x 10 2 x 12 2 x 12 2 x 15	120
Ex. 8 1-4 week 5-8 week	The participant executes push-ups with the support of the slings. The difficulty is increased throughout the training period.	1,2 3,4 5,6 7,8	2 x 5 2 x 8 2 x 8 2 x 10	120
Ex. 9 1-4 week 5-8 week	Both feet are hung off the ground, with the back on the ground, and the participant lifts the pelvis off the ground and then bends the knees. The difficulty is increased after four weeks.	1,2 3,4 5,6 7,8	2 x 10 2 x 12 2 x 12 2 x 15	120
Ex.10	The participant bends the knees on the ground. Both wrists are placed on the slings, and the trunk is pushed forward and backward repeatedly.	1,2 3,4 5,6 7,8	2 x 5 2 x 8 3 x 8 3 x 10	120
Ex. 11	The participant places one knee on the sling; with the other leg unsupported, both feet perform flexion and extension.	1,2 3,4 5,6 7,8	2 x 5 2 x 8 3 x 8 3 x 10	120

to reach a basketball board before and after the training program. The altitude was measured in three times, subtracting the height and arm length, and then the three measures were averaged.

Penalty and fixed position shots: The participants were positioned at the penalty and fixed side lines (Figure 2), and performed penalty and fixed position shoots according to standard instructions. The test was evaluated using the percentage of successful shots from a total of 20.

Lay-up over obstruction: The participants ran through five pre-set obstacles, which required them to spin to traverse the middle obstruction, and then jump to shoot under the basketball board (Figure 3). The test was not concluded until each participant performed a successful shot. The time consumed to complete the test was recorded.

Statistical Analysis

Data analysis was performed using the statistical software Statistical Package for the Social Science (SPSS) version 22.0. Data to describe the characteristics and experimental variables of the participant were calculated as mean ± standard deviation. The training and control groups were compared in terms of the dependent variables, namely, athletic performance, core strength, and core endurance, before and after the training program (eight weeks) and between the two groups at the same session. Student *t*-test was conducted to compare the measurements. The level of significance was set at $p < 0.05$.

RESULTS

Age, height, and weight were not significantly different between the two groups.

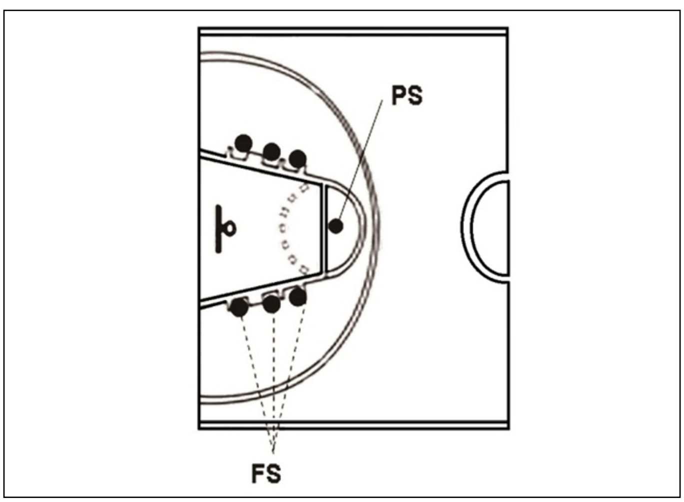

Figure 2. The position of penalty shot (PS) and positions of fixed shooting (FS) marked by black circles.

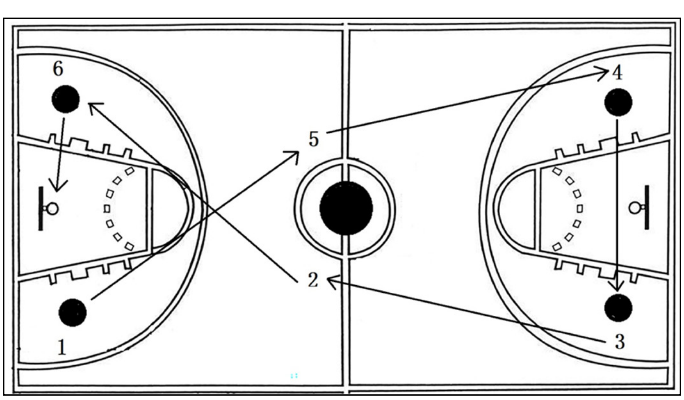

Figure 3. In the test an athlete runs and dribbles from 1-5-4-3-2-6 positions as fast as he can, and completes a jump shooting at position 6 (last arrow line). Big black circle indicates the obstruction at the middle of basketball court and other small black circles indicate the side obstructions under and beside the baskets.

Core endurance and strength

The training group exhibited significantly improved core endurance after completing the training program in the FET, EET, LLET, and RLET tests at post-assessment ($p < 0.01$) (Figure 4). The number of 60-s sit-up tests in the training group was significantly higher than that in the control group at post-assessment ($p < 0.01$) (Figure 4). The core endurance of subjects in the control group after the training did not improve compared with that before training ($p > 0.05$), except FET (Figure 4).

Basketball-specific performance

Both penalty and fixed position shots of two groups exhibited slight improvement at post-assessment after training, but not significant, $p > 0.05$ (Figure 5), and no difference was found between before and after training program. Jumping-reaching altitude in the two groups exhibited no change before or after training assessments (Figure 5).

No difference on the durations of lay-up over obstruction were found between the two groups before training, but became significantly shorter at post-assessment after the program than that before the training program in the training group, $p<0.01$ (Figure 5). The durations of lay-up over obstruction was significantly shorter in the training group than that in control group at post-assessment after the training program, $p<0.05$ (Figure 5).

DISCUSSION

Principal Results

The eight-week sling training program improved the durations of flexor, extensor, and lateral flexor of the trunk, and resulted in higher repetition of 60-s sit-ups in the training group. Lay-up over obstruction improved significantly in both training and control groups, but more gain was obtained for training group. This evidence indicated that sling exercises not only affect the core strength of the trunk, but also the basketball specific performance such as the speed of lay-up over obstruction.

This study confirmed that "core" stability is critical in athletic performance.[23] These findings indicated that completing the sling exercises increased the athletic core endurance and strength in the training group.

Effects of core stability exercise with slings

In sports, core becomes particularly important as it provides 'proximal stability for distal mobility.[24] Core stability proves to be an essential

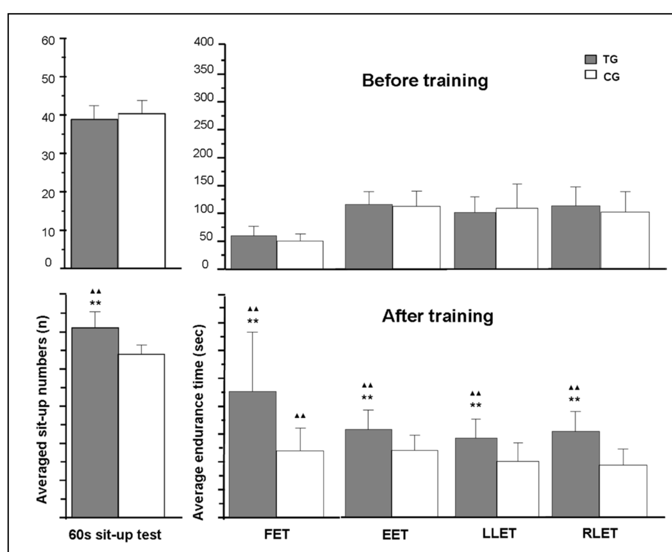

Figure 4. Histograms of averaged 60s sit-up number and endurance time. TG-training group and CG-control group. ** indicates p<0.01 between two groups. ▲▲ indicates p<0.01 between before and after training. Training refers to sling training. FET--Flexor endurance test, EET--extensor endurance test and left, LLET and RLET-- right lateral flexor endurance tests.

Table 2. Comparison 60s Sit-up Number and Endurance of the Two Groups Before and After the Experiment (Match to Fig. 4).

Gourps/Tests	60s Sit-up (n)	Endurance Time (s)			
		FET	EET	LLET	RLET
TG Before	38.8 ± 3.5	60.0 ± 16.4	115.9 ± 23.2	100.1 ± 27.3	112.3 ± 31.8
CG Before	40.5 ± 3.4	50.9 ± 12.3	112.7 ± 25.9	109.1 ± 41.8	104.1 ± 34.9
TG After	51.1 ± 4.1**▲▲	226.4 ± 106.7**▲▲	157.7 ± 35.9**▲▲	142.3 ± 34.9**▲▲	154.1 ± 36.8**▲▲
CG After	44.0 ± 2.3	119.5 ± 40.9▲▲	120.9 ± 26.8	101.3 ± 33.2	93.6 ± 29.1

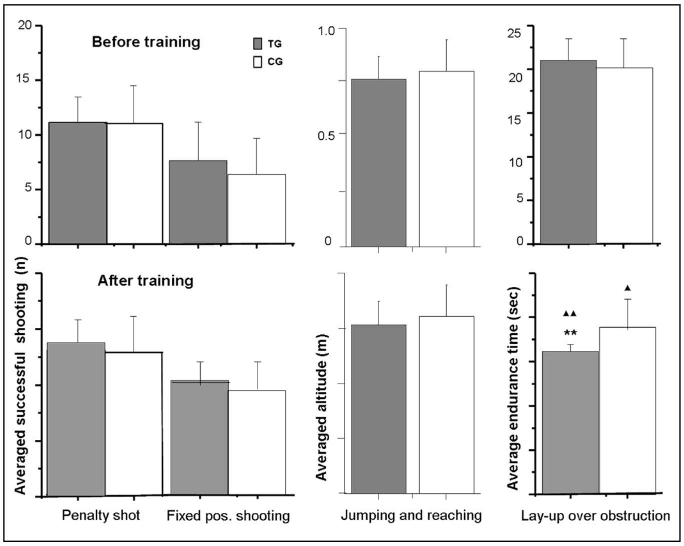

Figure 5. Histograms of averaged numbers of successful shooting, jumping-reaching altitude and duration of lay-ups over obstruction. TG-training group and CG-control group. ** indicates p<0.01 between two groups. ▲▲ indicates p<0.01 and ▲ p<0.05 between before and after training. Training refers to sling training.

Table 3. Comparison the Numbers of Successful Shooting, Jumping-reaching Altitude and Duration of Lay-ups Obstruction of the Two Groups Before and After the Experiment (Match to Fig. 5).

Gourps/Test	Penalty shot	Fixed pos. shooting	Jumping and reaching	Lay-up obstruction
TG Before	11.1 ± 2.3	7.6 ± 3.4	0.76 ± 0.1	21.0 ± 2.5
CG Before	11.0 ± 3.4	6.2 ± 3.2	0.79 ± 0.2	20.2 ± 3.3
TG After	13.8 ± 2.1	10.2 ± 1.7	0.77 ± 0.1	16.1 ± 0.8**▲▲
CG After	12.9 ± 3.2	9.6 ± 2.7	0.81 ± 0.2	18.8 ± 3.2▲

component of biomechanical efficiency as it leads to maximum force production thereby reducing the loads over peripheral joints.[24] The core muscles of the trunk and pelvis are responsible for maintaining the stability of the spine and pelvis and are critical for the transfer of energy from larger torso to smaller extremities during many sports activities.[25] The effects of core stability exercises incorporated with slings on untrained college students have been investigated in a pilot study.[26] Their results showed that the strength of the trunk flexor and right trunk lateral endurance improved, but not the athletic performance. This finding in the aspect of trunk endurance was slightly similar to that of the current study, but our results were better than theirs, because four directions of trunk endurances improved in our finding. A correlation study on core stability and athletic performance reported that 60-s sit-up test was reliable and moderately correlated with athletic performance measures.[27] Thus, this test was established as the optimal field-based core stability measure.[27] Our study validated the effectiveness of the 60-s sit-up test to monitor improvements. Compared with the group without sling exercise, sling exercise showed better effectiveness to increase trunk endurance and strength in the training group, Therefore, good trunk strength of an athlete is important. Movement control depends on muscle activation and strength relative to sport performances and injuries.[28] Several studies showed that the control of the trunk and lower extremity muscles changed for people in pain.[29–31] Moreover, pain is associated with compromised control, increasing the risk of injury or re-injury.

Effects of basketball-specific performance with slings

Previous studies also used specific athletic performance measures (i.e., maximal kicking velocity measurement with two photo cells and club-head velocity measurement for golfers).[11,12] The results showed that golf and kicking movements required more stability of the trunk to ensure a stable position. Therefore, the velocity of the club-head and feet could be achieved. However, the conditions of basketball-specific performance may not be similar to that of golf and kicking because a basketball shot and jumping-reaching altitude do not require significant speed of the extremity, but an accurate and immediate action. Both Gencer[21] and Stanton et al.[22] also reported that no increased performance were observed in swimming or running after core training, respectively. The research on core training leads to inconsistent results, which may be due to different sports characteristics, different exercise methods and different test indicators and so on. The current results did not exhibit improved basketball-specific performance in some aspects after core endurance was improved in the training group. However, the performance of lay-up over obstruction improved significantly after eight weeks of training in the sling training group and better than that in the non-sling group. The duration of this performance became significantly shorter in the training group than that in the control group. It means that the speed to complete lay-up over obstruction with sling exercise was faster than that without non-sling exercise. Researchers find whether forces generated from distal body segments or from expected or unexpected perturbations, Core stability is related to the body's ability to control the trunk in response to the forces.[32] When a limb is moved, reactive forces are imposed on the spine acting in parallel and opposing those producing the movement, which indicates the importance of muscular control of the spine during limb movement.[33] Moreover, transversus abdominis is a feed forward muscle and preactivates other trunk muscles during rapid arm raising 24. The increased speed of lay-up over obstruction was because basketball athletes have already gained trunk strength and core stability with sling exercise that the ability of the trunk control in response to the forces generated from lay-up over obstruction is better. At the meanwhile, the feed forward and preactivates of core muscles may lead to a faster reaction when doing lay-up over obstruction. However, it needs a further EMG study to clarify whether the increased speed of lay-up over obstruction in training group is related to the increased endurance of their trunk muscles.

CONCLUSION

This study showed that sling exercises can increase core strength and enhance athletic performance on speed of lay-up over obstruction of a basketball player. Therefore, this study provided new insights into the effects of core exercises with sling training on the core function of college basketball players. The positive effects of the core exercise protocol can assist coaches or physiotherapists in selecting training exercises that enable athletes to improve the endurance of their trunk muscles to improve the performance of lay-up over obstruction, as well as decrease the risk of trunk injury.

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