Vol.1 No.1 2021
https://doi.org/10.37420/j.ssp.2021.002

Effect of a Six-week Core Stability Training in Physical Education Classes on Dynamic Balance and Agility in Badminton Special Boys

Xiaodan Zhang*, Rongfang Chu, Zhenhao Yang
School of Physical Education and Education Science, Tianjin University of Sport, Tianjin, China
*Corresponding author, e-mail: zxd331@hotmail.com

Abstract: *To investigate the effects of 6 weeks of progressive core stability training on dynamic balance and agility in college male badminton students. 65 college students majoring in physical education were randomly divided into an experimental group (6 weeks of progressive core stability training) and a control group (6 weeks of regular physical training). The duration, frequency and intensity of physical training were the same in both groups. The results revealed that after the intervention: (1) The results and overall scores of the 8 directions of SEBT in the experimental group were better than those before the intervention, and there were no differences in the results of SEBT in all directions on the left and right sides. (2) The test results and comprehensive scores of the left leg supported under the experimental group were better than those of the control group in all directions except for the results in the anterolateral and lateral directions, and the results in the lateral and medial-anterior directions under the right leg support. (3) The reach distance of SEBT under left and right leg support in the control group was significantly increased only in the lateral direction compared with that before the intervention. (4) No significant change in agility was observed in both groups. Progressive core stability training can significantly improve the dynamic balance of boys specializing in badminton in college physical education, and promote the balanced development of dynamic balance on the left and right sides, but did not significantly improve their agility.*

Key words: *core stability training, dynamic balance, agility, badminton*

Badminton is one of the most popular racquet sports in the world (Sonoda, Tashiro, Suzuki, Kajiwara, Zeidan, Yokota, Kawagoe, Nakayama, Bito, Shimoura, Tatsumi, Nakai, Nishida, Yoshimi & Aoyama, 2018), and the sport requires the body to change direction quickly, jump, lunge forward, move the arms quickly and maintain a variety of postures, and constantly keep its center of gravity wwithin the point of support (Wong, Ma, Liu, Chung, Bae, Fong, Ganesan & Wang, 2019). Therefore excellent body balance, especially dynamic balance, is essential for the improvement of badminton skills, sports performance and prevention of sports injuries. Agility is defined as the ability to rapidly change speed or direction in response to stimuli during whole-body movement (Paul, Gabbett & Nassis, 2016). In badminton tournaments or training, agility is pivotal to either offense or defense and is a key variable for excellent badminton performance (Kuo, Tsai, Lin & Wu, 2020).

Dynamic balance and agility are important for badminton events, but they have not been adequately studied

Vol.1 No.1 2021
https://doi.org/10.37420/j.ssp.2021.002

(Wong, Ma, Liu & et al, 2019), and even less research has been conducted on the effects of core stability training on dynamic balance and agility in badminton events (Hassan, 2017), and no research has been reported on the effects of core stability training on the dynamic balance and agility of college students specializing in badminton. In this study, we investigated the effects of 6 weeks of progressive core stability training on the dynamic balance and agility of male students majoring in physical education specializing in badminton, in order to provide data support for further improvement of badminton teaching effects and improvement of students' special skills.

Research object and method

Object of the study

The Tianjin Institute of Physical Education was selected as the source school for the subjects based on the principle of convenience, and 35 male volunteers majoring in physical education were recruited to receive a 6-week progressive core stability training intervention. Thirty-two male students with an average of 1.8-2.0 years of special training were the control group.

Inclusion criteria: (1) no sports injury and lower extremity osteoarthritic disease, subjective consent to participate in a focused core stability training intervention lasting 6 weeks, 3 times a week, 20-25 minutes each time; (2) according to the results of the first test before the intervention, the objective organism is able to participate in this experiment. (3) The whole process needs to strictly comply with the experimental design and requirements. (4) Male students majoring in physical education with badminton specialization and who had not participated in core training before this study.

Exclusion criteria: (1) sports injury and suspension of training in the last 1 month; (2) failure to participate in all experiments and tests due to subjective and objective reasons. Finally, one person withdrew from the experiment due to a cold and fever, and one person sprained his ankle going downstairs, and a total of 65 male students specializing in badminton in physical education were included. All subjects signed the "Informed consent for the experiment on the effect of core stability training on dynamic balance and agility of badminton special boys" before the experiment, and the study was approved by the Ethics Committee of Tianjin Sports Institute (Grant No. 20200305).

Research methodology

Literature method

Review the literature to initially determine the evaluation indexes of core stability, dynamic balance, agility and the training content of core stability for badminton events.

Interview method

February 23-April 23, 2020 Consult relevant scholars and experts by phone interview or email on the primary indicators of core stability, dynamic balance, agility evaluation and core stability training content in badminton.

Test method

The core stability, dynamic balance and agility of all subjects were tested before and after the experiment from May 18 to June 26, 2020. All tests were conducted at the Badminton I Hall, 3rd Floor, Ping and Feather Hall, New Campus of Tianjin Sports Institute.

Five indicators of trunk flexion and extension range of motion, dominant side single-leg stance, dominant side single-leg jump, sit-ups, and trunk extensor endurance were used to reflect the subjects' core stability (Guo, Li, Wu, 2018). Each index was tested 3 times, with a 2-minute rest between groups, and the mean of the 3 times results was taken, and the results were retained to one decimal place.

The star excursion balance test (SEBT) was used to reflect the dynamic balance ability of the subjects (Hassan, 2017; Ozmen & Aydogmus, 2016; Watson, Graning, McPherson, Carter, Edwards, Melcher & Burgess, 2017). In order to more objectively reflect the extension distance of the subject's lower limbs and exclude the interference of the absolute value of leg length, the leg length data of all subjects were standardized in this study, i.e., the relative distance in each direction (% lower limb length) = the mean value of 3 extensions of the non-supported leg/leg length × 100 (Gribble & Hertel, 2003). Where leg length is the distance from the anterior superior iliac spine to the most prominent bone point on the medial aspect of the ipsilateral calf using a standard tape measure while the subject is supine on the treatment table. The direction of reach was determined by taping three tape measures to the gym floor. Before the test began, the subject stood with the support leg in the center of the grid. The grid consisted of 8 tape measures, each with an angle of 45°between them. The combined score = the sum of the mean of the 3 extensions of the non-supported leg in the 8 directions)/(8 times the leg length) × 100 (Imai, Kaneoka, Okubo & Shiraki, 2014). A total of 3 measurements were taken, with a 2-minute rest between sets, and the average of the 3 scores was taken, with the results retained to one decimal place.

The T-test was used to reflect the subject's agility. Subjects stood at the starting point facing the forward direction and ran 10 yards to the middle marker as fast as possible, then slid 5 yards right to the right marker, then slid 10 yards left to the left marker, then slid 5 yards right to the middle marker and then backed up to run 10 yards to the finish line (Syed, Shibili, Reenika & et al, 2019). The stopwatch recorded the time used for the whole course. A total of 3 tests were performed, with 2 minutes rest between groups, and the average of the 3 results was taken, and the results were retained to two decimal places.

Experimental method

Pre-experiment. from April 30 to May 15, 2020, randomly selected physical education majors specializing in badminton outside this experiment conducted a pre-experiment on core stability training. Adjust the exercise volume, intensity and difficulty of the formal experiment according to the results of the pre-experiment.

Vol.1 No.1 2021
https://doi.org/10.37420/j.ssp.2021.002

Formal experiment. 6 weeks of progressive core stability training for 3 times/week (Tuesday, Thursday, Friday) for 20-25 minutes/time was conducted for the experimental group from May 18-June 26, 2020. The progressive core stability training program consisted of 2 weeks each of steady-state kinetic exercises, non-steady-state static exercises, and non-steady-state dynamic exercises. The control group underwent 6 weeks of conventional physical training, and the periodicity, frequency and intensity of training were the same as those of the experimental group.

To ensure the quality of experiments and tests, the relevant controls are as follows.

(1) Homogeneity of subjects: all subjects were from three parallel classes of physical education majors in Tianjin Institute of Physical Education. The courses taken and daily living habits were basically the same. The results of the pre-test showed that there was no statistical difference in basic condition, initial core stability, initial dynamic balance, and initial agility between the two groups, which were homogeneous.

(2) High subject compliance: all subjects cooperated fully during the experimental period, and the rest of the training, diet and routine were consistent in both groups, except for the core stability training content prescribed in this study. The adaptation to core training was low in both groups because there was no specific core training in their daily physical training regimen. At the same time, in order to exclude the influence of changes in the physical training program outside the experiment on the test results, the original physical training content and load of the two groups were required to be consistent before and after the experiment.

(3) Professionalism of experimental and testing personnel: In order to ensure the accuracy and validity of the experiments and tests, the senior lab technician of the University was invited to conduct uniform professional training for the personnel involved in this study. At the same time, the whole experiments were done by the same group of professionals in the same indoor location before and after the tests. The room temperature was controlled at 22~24°C and was not disturbed by the surrounding environment.

Mathematical and statistical method

All data were statistically analyzed by SPSS 26.0 statistical software. The K-S test was used to test whether the data obeyed a normal distribution. If they obeyed normal distribution, the paired t-test was used to analyze the differences within each group separately, and the independent samples t-test was used to analyze the differences between the two groups. If the data did not obey normal distribution, Wilcoxon rank test and Mann-Whitney U test were used, respectively. The significance level was set at $P< 0.05$.

Results

Subjects' basic information

The basic conditions of all subjects were collated and counted (Table 1). k-S test showed that the data of basic conditions of all subjects were normally distributed.

Table 1

Basic information of subjects (N=65)

Group	Age(y)	Height(cm)	Body weight(kg)	Campaign years(y)	Lower limb length(cm)
Experimental group (N=33)	20.9±1.4	174.1±4.8	68.9±9.6	1.9±0.2	87.4±2.5
Control group (N=32)	19.9±0.8	176.2±3.7	69.1±4.3	1.8±0.1	88.9±1.9

*Compared with pre-experimental, *P<0.05, **P<0.01; compared with control, #P<0.05, ##P<0.01.*

The independent samples t-test showed that there was no statistical difference between the two groups of subjects in all basic conditions (all P values > 0.05).

Comparison of core stability of subjects before and after the intervention

Guo Liang believed that the components of core stability include five dimensions, including core strength, core endurance, core flexibility, core control, and core functionality (Guo, Li & Wu, 2018). In this study, the evaluation indexes of core stability were designed accordingly and expert interviews were conducted. The results yielded five indicators of trunk flexion and extension range of motion, dominant-side single-leg stance, dominant-side single-leg jump, sit-ups, and trunk extensor endurance as representative indicators of the above five dimensions. Subjects were tested for core stability based on these five indices.

The K-S test showed that the pre-test data of core stability of all subjects obeyed normal distribution. The independent samples t-test showed that there was no significant difference between the two groups before the intervention of the five tested indexes (all P values > 0.05) (Table 2), suggesting that the level of core stability of the subjects in the two groups before the experiment was homogeneous.

Table 2

Comparison of core stability-related test indicators between the two groups of subjects before and after the intervention (N=65)

Group	Indicators	TFE(cm)	DLS(s)	DLH(cm)	SU(times/min)	EE(s)
Experimental group (N = 33)	Pre-experiment	10.5±3.0	19.9±9.0	195.5±7.5	46.1±8.0	78.4±9.2
	After the experiment	14.1±2.7#**	41.3±4.4#**	208.3±4.8#**	51.5±2.9##*	94.0±3.9##*
Control group (N = 32)	Pre-experiment	9.8±3.9	22.5±9.2	191.0±9.1	47.0±7.3	83.4±13.2
	After the experiment	9.2±5.8	35.3±5.8*	199.4±3.7*	45.7±3.6	83.9±8.8

TEE: trunk flexion and extension range of motion; DLS: dominant side single-leg stance; DLH: dominant side single-leg jump; SU: sit-up.

EE: Trunk extensor endurance.

*Compared with itself, *P<0.05, **P<0.01; compared with the control group, #P<0.05 and ##P<0.01.*

The results of the K-S test also indicated that the five posttest indicators of core stability of the subjects were

Vol.1 No.1 2021
https://doi.org/10.37420/j.ssp.2021.002

normally distributed. The differences in the five posttest indicators of intervention between the two groups of subjects were compared by independent samples t-test. The results showed that all five test indicators in the experimental group were higher than those in the control group (all P values < 0.05). Especially, the sit-ups and trunk extensor endurance indexes (all P values < 0.01) (Table 2).

Paired-samples t-test was used to examine the core stability data of the experimental group before and after the intervention, and the results showed that the five core stability data of the experimental group were significantly improved after the intervention (all P-values < 0.05). Among them, the most significant improvement was found in trunk flexion and extension range of motion, dominant side single-leg stance, and dominant side single-leg long jump (all P values < 0.01).

Paired t-tests revealed that there was a significant improvement in dominant-side single-leg stand (P< 0.05) and dominant-side single-leg jump (P< 0.05) in the control group after the intervention, and there were no statistical differences in the changes of other indicators (all P values > 0.05) (Table 2).

Comparison of subjects' dynamic balance ability before and after the intervention

After reviewing the literature and interviewing experts, it was determined that the evaluation index of dynamic balance ability in this study was the star excursion balance test (SEBT).

The K-S test proved that all the pre-test indicators in the subjects' star deflection balance test obeyed normal distribution. An independent samples t-test of the SEBT results of the subjects in the two groups before the experiment revealed that there was no significant difference between the test results of the two groups in the eight directions and the overall performance under left and right leg support (all P values > 0.05) (Table 3).

Table 3

Comparison of SEBT test results between the two groups of subjects before and after the intervention (N=65) [% lower limb length]

Support leg	Indicators	Experimental group (N = 33)		Control group (N = 32)	
		Pre-experiment	After the experiment	Pre-experiment	After the experiment
left Legs support brace	Ex	84.5±7.2	97.8±6.$^{3££}$	85.4±7.6	86.4±4.9
	Outside front	73.2±7.8	87.4±5.$^{3\#\#££}$	75.2±8.8	77.4±6.6
	Outside	66.3±14.1	81.9±8.$^{1£}$	68.0±12.8	77.6±8.$^{7£}$
	Outside Back	82.9±13.7	97.1±6.$^{6\#££}$	76.5±13.1	83.9±5.3
	After	90.3±14.1	101.1±7.$^{8\#£}$	89.5±12.8	92.9±9.2
	Inside Back	83.5±13.2	103.3±8.$^{3\#£}$	88.7±12.8	90.2±9.5
	Inside	90.8±11.8	99.1±6.$^{5\#£}$	87.9±10.8	89.3±7.6
	Inside the front	90.8±9.0	97.6±3.$^{3\#£}$	90.3±8.3	91.9±3.1
	Comprehensive	84.1±11.1	93.8±6.$^{2\#££}$	83.7±10.8	84.3±6.6
Right Legs support brace	Ex	84.1±6.8	96.2±5.$^{8\#££}$	85.0±7.6	91.2±5.^{8*}
	Outside front	79.4±9.^{0**}	86.2±3.$^{1\#\#£}$	81.7±10.^{3**}	82.1±3.^{8*}
	Outside	65.6±13.1	81.1±9.$^{1££}$	66.5±14.2	81.2±7.$^{5£}$
	Outside Back	81.7±14.6	96.2±5.$^{2\#\#££}$	82.3±13.^{5*}	83.1±5.3
	After	90.1±12.8	99.5±5.$^{2\#££}$	88.8±14.1	91.7±4.8
	Inside Back	90.2±14.^{0*}	102.5±5.$^{1\#\#££}$	89.9±13.9	91.7±4.2
	Inside	90.2±13.5	99.4±5.$^{5\#££}$	89.7±12.7	94.5±3.^{1*}
	Inside the front	90.1±9.3	96.7±3.$^{9£}$	89.6±9.6	90.8±6.2
	Comprehensive	83.8±11.2	93.4±5.$^{1\#££}$	83.7±12.0	85.1±4.8

**P<0.05, **P<0.01 compared to own left leg during the same period; #P<0.05, ##P<0.01 compared to control group.*
£P<0.05, ££P<0.01 compared to own ipsilateral before the experiment.

In addition, the intra-group differences in the results of the SEBT test under the left and right support legs were compared between the two groups of subjects before the intervention, and the results showed that the reach distance (% lower limb length) under the right leg support in the external anterior direction was significantly higher than that under the left leg support in both groups (both P values < 0.01), and the reach distance (% lower limb length) under the right leg support in the external posterior direction in the control group and in the internal posterior direction under the right leg support in the experimental group significantly exceeded the reach distance of own left leg support (all P-values < 0.05).

After the intervention, the standardized values of SEBT post-test indicators in both groups of subjects obeyed normal distribution. The independent samples t-test showed that the standardized values under the left leg support of the experimental group were better than those of the control group in all six directions and in the overall performance (P-value < 0.05), except for the standardized values in the anterior and lateral directions, which were not statistically different from each other (P-value > 0.05). The distance in the external anterior direction (% lower limb length) was significantly farther than that of the control group (P<0.01). With the right leg support, the experimental group outperformed the control group in all six directions and overall performance (P value < 0.05), except for the standard values in the lateral and medial-anterior directions, which were not statistically different from the control group (all P values > 0.05). The reach distances (% lower limb length) in the external anterior, external posterior and internal posterior directions were significantly higher than those in the control group (all P values < 0.01) (Table 3). Although some of the SEBT post-test results were not statistically different between the two groups of subjects, the overall test results of the experimental group were better than those of the control group.

The intra-group differences in SEBT test results between the two groups of subjects under left and right leg support were compared again after the intervention, and it was found that the reach distances in the anterolateral, posterolateral and medial directions were significantly higher in the control group under right leg support than under left leg support (all P values < 0.05), while the scores in all directions and the overall scores in the SEBT test under left and right leg support in the experimental group were close and all statistically different (all P values > 0.05).

Paired-samples t-test was used to compare the SEBT data before and after the experiment in the control group, and it was found that after 6 weeks of conventional physical training, only the reach distance in the lateral direction under the support of the left and right legs increased significantly in the control group compared with that before the intervention (all P values < 0.05), and the rest of the directions and the overall performance showed a small increase but no significant change (all P values > 0.05).

Similarly, the core stability data of the experimental group before and after the experiment were tested by paired-sample t-test, and the results showed that the left and right legs supported under each direction and comprehensive performance of the experimental group after the 6-week core stability training intervention were significantly better than those before the intervention. Among them, the anterolateral, posterolateral, posteroposterior directions and comprehensive performance under left leg support and the anterolateral,

Vol.1 No.1 2021
https://doi.org/10.37420/j.ssp.2021.002

posteroposterior, posteroposterior, medial posterior and medial directions and comprehensive performance under right leg support were significantly improved (all P values < 0.01).

Comparison of agility of subjects before and after the intervention

Based on the review of literature and interviews with experts, this study determined that the evaluation index of agility of badminton items was the T-test. The K-S test proved that the subjects' T-test pre-test indexes obeyed normal distribution. Independent samples t-test was conducted on the pre-test results of the two groups of subjects and it was found that there was no statistical difference in the T-test results between the groups (all P values > 0.05). Similarly, no statistical difference was found between the groups for the post-test results (p-values > 0.05) (Table 4).

Table 4

Comparison of T-test results between the two groups of subjects before and after the intervention (N=65)

Indicators	Experimental group (N = 33)		Control group (N = 32)	
	Pre-experiment	After the experiment	Pre-experiment	After the experiment
T-test	10.07±1.29	9.98±1.33	10.13±1.17	10.09±1.24

*Compared with pre-experimental, *P<0.05, **P<0.01; compared with control, #P<0.05, ##P<0.01.*

Discussion

Core stability has proven to be essential in many sports, and core stability training has become an integral and important part of modern physical training. There are many different methods of core stability training. For example, Hoppes' 8-week core stability training with subjects included static, dynamic, and kinesthetic training methods in steady state (Hoppes, Sperier, Hopkins, et al, 2016); Hongju et al. used unstable planes such as the Swiss ball for core stability training with subjects (Liu, Li, Du, et al, 2019). The results of all of these studies showed that core stability was improved after 8-12 weeks of core stability training. Accordingly, this study used static, dynamic and combined kinetic training methods in the first phase of steady state, and also used an unstable apparatus, the Swiss ball, for progressive core stability training in the second and third phases, as a way to increase the difficulty and load of the exercises for the experimental group.

To the authors' knowledge, this is the first study to examine the effects of core stability training in physical education classes on dynamic balance and agility in college male badminton specialists. The results showed that the 6-week progressive core stability training resulted in significant improvements in core stability and dynamic balance, but had little effect on agility compared to conventional physical training.

Compared to similar studies (Ozmen, Aydogmus, 2016;Olmsted, Carcia, Hertel, et al, 2002;Imai, Kaneoka, Okubo, et al, 2014), the present study had the shortest duration, few all devices, and used the Swiss ball only in the second and third phases, but the improvement in the subjects' dynamic balance was significant and resulted in a more balanced dynamic balance with left and right foot support.

The effect of core stability training on the dynamic balance of badminton special boys

The control of body balance is an integrated process of neuromuscular activity. In this process the organism relies mainly on the nerve impulses sent by the vestibular organs, visual and proprioceptive systems in response to stimuli and their integration of information, accompanied by the synergistic action of the various muscle functions, which ultimately leads to the effective control of motor effectors (Jadczak, Grygorowicz, Wieczorek, et al, 2019). According to the nature of Balance, it can be divided into static and dynamic Balance. The importance of dynamic Balance in the motor process is more evident since the organism is less likely to be static and more likely to be dynamically balanced during movement (Guzmán-Muñoz, Valdes, Méndez-Rebolledo, et al, 2019).

Dynamic balance is one of the most important motor skills and is considered to be the ability to maintain or regain a stable position when performing a given movement (Maszczyk, Gołaś, Pietraszewski, et al, 2018), or the ability to maintain or regain balance on an unstable surface with minimal external motion (Szafraniec, Chromik, Poborska, et al, 2018). For most sports, improving dynamic balance can improve overall athletic performance (Rafał, Janusz, Adam, 2020).

Badminton is an inter-net confrontation type of skill sport. Although there is no direct physical contact in the sport, good dynamic balance is essential in badminton due to the constant change of attack and defense and the constant change of rhythm, which requires the body to change its posture and maintain the body posture in a series of movements such as rapid change of direction, jumping, forward lunge, and rapid arm swing (Towel, Ada, Karen, et al, 2019).

Combining the special characteristics of badminton and the results of expert interviews, this study selected star offset balance as the evaluation index of dynamic balance ability in badminton events (Olmsted, Carcia, Hertel, et al, 2002). After a 6-week core stability training for the experimental group, it was found that the test results and overall scores of all directions in the SEBT test under the left and right support legs of the experimental group were significantly higher than those before the intervention. In particular, the test results and comprehensive scores in the anterior, external anterior and external posterior directions under the left leg support and the test results and comprehensive scores in the external direction under the right leg support were significantly higher. In addition to this, the results and comprehensive scores of the experimental group in the direction under the left leg support in the anterior and lateral, and the right leg support in the lateral and medial-anterior directions were significantly increased compared with those before the intervention, except for the left leg support in the anterior and lateral, and the right leg support in the lateral and medial-anterior directions, which did not have significant changes; and the test results of some directions were significantly higher than those of the control group, although they did not have significant changes from those before the intervention itself. This is similar to the results of Olmste's study(Olmsted, Carcia, Hertel, et al, 2002).

Sandrey noted that a 6-week core stabilization training intervention (30 min × three times per week) significantly enhanced dynamic balance in high school track and field athletes. The reason for this may be that the agility and strength of the hip and thigh muscles that move the limb in the direction of the target affects reach when participants stand on one foot during SEBT (Guo, Li, Wu, 2018). Similarly, similar results

Vol.1 No.1 2021
https://doi.org/10.37420/j.ssp.2021.002

were obtained in high school soccer players after a 12-week period of core stability training (3 times per week) (Imai, Kaneoka, Okubo & Shiraki, 2014).Granacher compared the effects of core stability training on stable and unstable surfaces. In particular, after 6 weeks of core stability training on an unstable surface, 27 adolescents showed a 2-3% improvement in balance (Watson, Graning, McPherson & et al, 2017). Similarly, dynamic balance was improved in badminton players after 8 weeks of core stability training (Hassan, 2017; Guo, Li & Wu, 2018). A 9-week core stability training program (30 minutes × 3 times per week) improved the dynamic balance of college competitive dancers (Ozmen & Aydogmus, 2016). In this study, by gradually implementing progressive core stability training on static stable surface-dynamic stable surface-dynamic unstable surface, the subjects' reach distance and overall performance in different directions of SEBT were significantly improved. Meanwhile, after 6 weeks of core stability training intervention, the SEBT imbalance under left and right leg support before the experiment disappeared. In conclusion, compared with conventional physical training, core stability training helps to improve the dynamic balance level and left-right balance development of badminton special boys. Core stability mainly includes passive subsystem, active subsystem, and neural control subsystem. The mutual compensation of the three subsystems in function provides the relative stability of the body core (Katarzyna & George, 2021).

Changes in agility of subjects before and after the experiment

It is well known that badminton requires a high degree of agility in the body. When the upper and lower limbs move rapidly in different directions, strong core muscle strength is required. Some scholars believe that core stability training can improve the agility of the subjects. For example, Syed found that after 5 weeks of core stability training in 30 junior tennis players, dynamic balance and agility were improved in the experimental group compared to the control group (Watson, Graning, McPherson & et al, 2017). However, more literature confirms that the effect of core stability training on agility is not significant. The present study experimentally confirmed that 6 weeks of progressive core stability training did not significantly improve the agility of boys specializing in badminton in physical education.

Nesser et al. did not find a significant relationship between core stability and agility or sprinting (Nesser & Lee, 2009). He suggested that strong core muscles may provide support to the lower extremities during agility tests, but that explosive exercises for the lower extremities may be more effective in developing agility. Therefore, this may be the reason why the participants' agility did not significantly improve after 6 weeks of core stability training.

The Schilling study showed that core stability training twice a week for 6 weeks resulted in significant improvements in dorsiflexor endurance, flexor endurance, and lateral recumbent endurance in 10 untrained college students. However, their agility, sprinting and vertical jumping abilities did not improve (Schilling, Murphy, Bonney & Thich, 2013). The reason for this may be that core stability training is not the only contributing factor to these qualities. Therefore, it is recommended that strength training be added to agility exercises and that a longer training program may be required to see significant improvements in agility.

This study experimentally confirmed the effects of 6 weeks of progressive core stability training on dynamic balance and agility in male college students specializing in badminton in physical education, providing an evidence base for targeted instruction and motor skill improvement. This study also has certain shortcomings, firstly, lower limb kinematics may affect dynamic balance, but this study did not consider this confounding factor when analyzing the data. Second, the results of this study were obtained with a sample of male college students majoring in physical education with badminton specialization, so it is not appropriate to generalize to badminton players of other training levels.

Conclusions

(1) Progressive core stability training helps to improve core stability and dynamic balance significantly, and is beneficial to the balanced development of the dynamic balance capacity of the left and right sides of the organism. This is related to the mutual compensatory effect of the three subsystems in function.

(2) Progressive core stability training did not significantly improve agility in the subjects. Explosive exercises for the lower extremities may be more effective in developing agility, or longer core stability training may be required to see significant improvements in agility.

References

Sonoda, T., Tashiro, Y., Suzuki, Y., Kajiwara, Y., Zeidan, H., Yokota, Y., Kawagoe, M., Nakayama, Y., Bito, T., Shimoura, K., Tatsumi, M., Nakai, K., Nishida, Y., Yoshimi, S., & Aoyama, T. (2018). Relationship between agility and lower limb muscle strength, targeting university badminton players. *Journal of physical therapy science,* 30(2), 320–323.

Wong, T., Ma, A., Liu, K., Chung, L., Bae, Y. H., Fong, S., Ganesan, B., & Wang, H. K. (2019). Balance control, agility, eye-hand coordination, and sport performance of amateur badminton players: A cross-sectional study. *Medicine,* 98(2), e14134.

Paul, D. J., Gabbett, T. J., & Nassis, G. P. (2016). Agility in Team Sports: Testing, Training and Factors Affecting Performance. *Sports medicine (Auckland, N.Z.),* 46(3), 421–442.

Kuo, K. P., Tsai, H. H., Lin, C. Y., & Wu, W. T. (2020). Verification and Evaluation of a Visual Reaction System for Badminton Training. *Sensors (Basel, Switzerland),* 20(23), 6808.

Hassan, I. H., (2017). The effect of core stability training on dynamic balance and smash stroke performance in badminton players. *International Journal of Sports Science and Physical Education,* 2(3), 44-52.

Guo, L.,Li, L. I., &Wu, Y.,(2018). The relationship between core stability related measurements and countermovement jump height with/without arm swing. *China Sport Science*, (04), 67-72.

Ozmen, T., & Aydogmus, M., (2016). Effect of core strength training on dynamic balance and agility in adolescent badminton players. *Journal of bodywork and movement therapies,* 20(3), 565–570.

Watson, T., Graning, J., McPherson, S., Carter, E., Edwards, J., Melcher, I., & Burgess, T. (2017). DANCE, BALANCE AND CORE MUSCLE PERFORMANCE MEASURES ARE IMPROVED FOLLOWING A 9-WEEK CORE STABILIZATION TRAINING PROGRAM AMONG COMPETITIVE COLLEGIATE Dancers. *International journal of sports physical therapy,* 12(1), 25–41.

Gribble, P. A., & Hertel, J. (2003). Considerations for normalizing measures of the Star Excursion Balance Test. *Measurement in physical education and exercise science,* 7(2), 89-100.

Bashir, S. F., Nuhmani, S., Dhall, R., & Muaidi, Q. I. (2019). Effect of core training on dynamic balance and agility among Indian junior tennis players. *Journal of back and musculoskeletal rehabilitation,* 32(2),

Vol.1 No.1 2021
https://doi.org/10.37420/j.ssp.2021.002

245–252.

Hoppes, C. W., Sperier, A. D., Hopkins, C. F., Griffiths, B. D., Principe, M. F., Schnall, B. L., Bell, J. C., & Koppenhaver, S. L. (2016).The efficacy of an eight-week core stabilization program on core muscle function and endurance: a randomized trial. *International journal of sports physical therapy,* 11(4), 507–519.

Olmsted, L. C., Carcia, C. R., Hertel, J., & Shultz, S. J. (2002). Efficacy of the Star Excursion Balance Tests in Detecting Reach Deficits in Subjects With Chronic Ankle Instability. *Journal of athletic training,* 37(4), 501–506.

Imai, A., Kaneoka, K., Okubo, Y., & Shiraki, H. (2014). Effects of two types of trunk exercises on balance and athletic performance in youth soccer players. *International journal of sports physical therapy,* 9(1), 47–57.

Liu, H., Li, J., Du, L., Yang, M., Yang, D., Li, J., Gao, F., & Ma, K. (2019). Short-term effects of core stability training on the balance and ambulation function of individuals with chronic spinal cord injury: a pilot randomized controlled trial. *Minerva medica,* 110(3), 216–223.

Jadczak, Ł., Grygorowicz, M., Wieczorek, A., & Śliwowski, R. (2019). Analysis of static balance performance and dynamic postural priority according to playing position in elite soccer players. *Gait & posture,* 74, 148–153.

Guzmán-Muñoz, E., Valdes Badilla, P., Méndez-Rebolledo, G., Concha-Cisternas, Y. F., & Castillo Retamal, M. (2019). Relación entre el perfil antropométrico y el balance postural estático y dinámico en niños de 6 a 9 años [Relationship between anthropometry and balance of postural control in children 6-9 years old]. *Nutricion hospitalaria,* 36(1), 32–38.

Maszczyk, A., Gołaś, A., Pietraszewski, P., Kowalczyk, M., Cięszczyk, P., Kochanowicz, A., Smółka, W., & Zając, A. (2018). Neurofeedback for the enhancement of dynamic balance of judokas. *Biology of sport,* 35(1), 99–102.

Szafraniec, R., Chromik, K., Poborska, A., & Kawczyński, A. (2018). Acute effects of contract-relax proprioceptive neuromuscular facilitation stretching of hip abductors and adductors on dynamic balance. *PeerJ*, 6, e6108.

Szafraniec, R., Bartkowski, J., & Kawczyński, A. (2020). Effects of Short-Term Core Stability Training on Dynamic Balance and Trunk Muscle Endurance in Novice Olympic Weightlifters. *Journal of human kinetics*, 74, 43–50.

Studnicka, K., & Ampat, G. (2021). *Lumbar Stabilization*. In StatPearls. StatPearls Publishing.

T. W., & Lee, W. L. (2009). THE RELATIONSHIP BETWEEN CORE STRENGTH AND PERFORMANCE IN DIVISION I FEMALE SOCCER PLAYERS. *Journal of exercise physiology online*, 12(2).

Schilling, J. F., Murphy, J. C., Bonney, J. R., & Thich, J. L. (2013). Effect of core strength and endurance training on performance in college students: randomized pilot study. *Journal of bodywork and movement therapies*, 17(3), 278–290.