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Original Research

The Effects of 12-week Online-delivered Isometric and Dynamic Core Stability Exercises on Functional Movement, Dynamic Postural Control, and Core Endurance in Healthy Young Adults

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ABSTRACT

OBJECTIVES The purpose of this study was to compare the effects of 12-week online-delivered isometric and dynamic core stability exercises on functional movements, dynamic postural control, and core endurance in healthy young adults.

METHODS This is a single-blind randomized controlled trial. Sixty young adults (age range: 19-34 years; 12 males, 48 females) participated in this study. They were randomly assigned to the isometric core exercise [ICE], dynamic core exercise [DCE], or control group. Participants in the ICE and DCE groups performed 40-60 min real-time online-delivered core exercise session via Zoom video conferencing application, twice a week for 12 weeks. Participants in the control group did not participate in exercise intervention. All participants were asked not to participate in other exercises for 12 weeks. The outcome measurements include the functional movement screen, Y-balance test (upper & lower), and core endurance tests (flexor, extensor, and lateral flexor of the trunk).

RESULTS The results of this study showed significant improvement in core endurance, functional movement, and dynamic postural control of the upper body in the ICT and DCE groups compared with the control group. However, significant differences were not found between the ICE and DCE groups in all variables.

CONCLUSIONS Both types of online-delivered core exercise programs have been shown to be effective in improving functional movement, dynamic posture control, and core endurance in young adults. In addition, since both types of exercise have been shown to be effective on core stability related variables, both types of exercise can be recommended for young adults. However, further studies are warranted to investigate the gender differences on the effects of the core stability exercises.

Introduction

The core of the body includes the spine, pelvis, hip joints, and abdominal regions [1, 2]. The muscles that comprise the core can be described as a box or cylinder. The superior part of the box is the diaphragm; inferior part, pelvic floor muscles; anterior and lateral parts, abdominal muscles; and posterior part, paraspinal and gluteal muscles [3]. The core muscles can be classified into global (or superficial) muscles and local (or deep) muscles [3, 4]. The global muscles include rectus abdominis, external oblique, quadratus lumborum, and erector spinae muscles [3, 4]. The local muscles include transverse abdominis, internal oblique, multifidus,

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pelvic floor muscles, and diaphragm [3, 4].

Core stability is defined as "the ability to achieve and sustain control of the trunk region at rest and during precise movement" through the expert consensus [5]. It plays an important role in human movements because it provides trunk stability for the mobility of the upper and lower extremities [2]. However, the muscles that comprise core stability are controversial. As a result of a Delphi study by an expert group, the muscles that comprise core stability were the transversus abdominis, internal oblique, external oblique, rectus abdominis, and multifidus [5].

Core strength refers to the ability to maintain balance the trunk through muscular contractile forces and intra-abdominal pressure [6]. Core endurance refers to the ability to maintain a static posture or perform repetitive movements for a long period of time [7, 8]. Improved core endurance can increase the time to maintain the core stable, which can increase the time to transmit or generate force from the trunk to the upper and lower extremities while performing sports or daily living activities [9]. Therefore, core strength and endurance are considered important factors in core stability.

Functional movement refers to the ability to maintain a balance between mobility and stability of the whole body while accurately and efficiently performing fundamental movement patterns [10]. Fundamental movement pattern refers to a movement that simultaneously requires muscle strength, joint range of motion, coordination, balance ability, and proprioception [11-13]. The functional movement screen (FMS) is a screening tool for identifying compensatory movement patterns that cause injuries and reduce athletic performance [11, 14]. It consists of seven functional movements. These movements assess core stability, neuromuscular control, movement asymmetry, and flexibility [11, 12]. Therefore, core stability is considered to be an important factor in perfectly performing the functional movements.

Postural control is the ability to maintain the line of gravity within the base of support [15, 16]. Dynamic postural control is the ability to maintain postural control while moving from a dynamic state to a static state [16]. The Y-balance test (YBT) upper quarter (UQ) and lower quarter (LQ) are assessment tools to measure dynamic postural control of the upper and lower extremities [17, 18]. Core stability is one of the primary factors required to perform these tests [18, 19]. A recent systematic review and meta-analysis study showed that core exercise moderately improves dynamic postural control in athletes and a non-trained population [20]. However, this study did not compare the effects of isometric and dynamic core stability exercises on dynamic postural control.

Abnormal movement patterns, movement asymmetry, and poor dynamic postural control are considered primary risk factors for non-contact injuries in athletes [17]. These risk factors are greatly influenced by core stability. Since the hip muscles are attached to the pelvis and lumbar vertebrae, poor core stability causes instability in these proximal ends of the hip muscles [21]. It decreases the control of the lower extremity while performing functional movements and load bearing movements, and it increases the risk of injury [19, 21]. Therefore, enhancing core stability may improve these risk factors and reduce the risk of non-contact injuries.

Poor core stability has been related to anterior cruciate ligament injuries and patellofemoral pain syndrome [22], as well as upper extremity injuries in athletes [23]. On the other hand, Huxel Bliven and Anderson [19] demonstrated that improving core stability contributes to the prevention of the risk of musculoskeletal injuries.

Based on the results of previous studies, core stability greatly affects human movements including functional movements and dynamic postural control.

A recent randomized controlled trial study showed that an online pilates exercise program included core exercises improves core muscle endurance in healthy young adults [24]. However, only few studies have investigated on the effects of online-delivered non-face-to-face core stability exercise programs on functional movements, dynamic postural control, and core endurance in healthy young adults. Since face-to-face exercise program is difficult to perform because of the coronavirus disease 2019 (COVID-19) pandemic, confirmation of the effectiveness of online-delivered non-face-to-face core stability exercise program on these variables is considered important.

In addition, whether dynamic core stability exercise

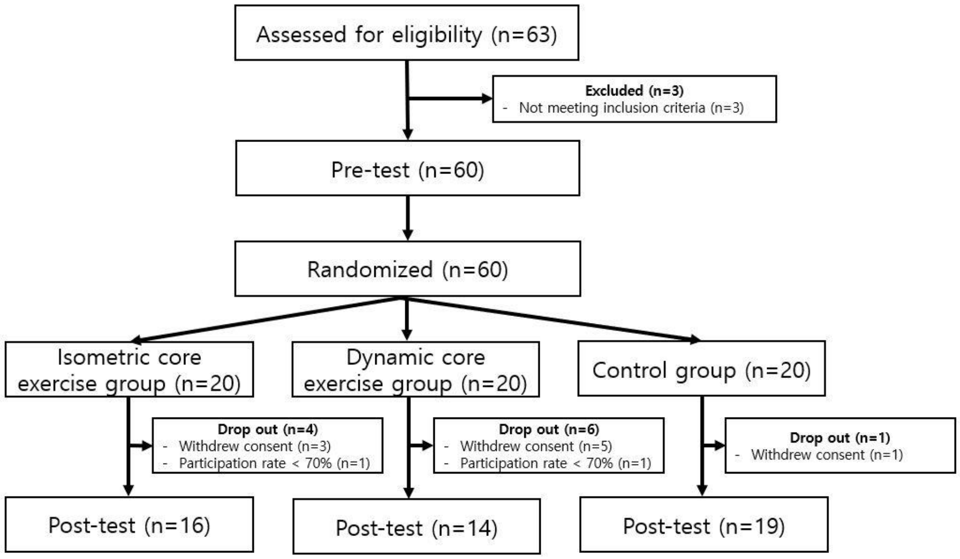

Figure 1. Flow chart of the study.

or isometric core stability exercise is more effective in improving core stability in healthy young adults is unclear. Saeterbakken et al. [25] demonstrated that there were no significant differences between isometric and dynamic core exercise groups on climbing performance in highly trained young climbers. Orgun et al. [26] showed that there were no significant differences between isometric and dynamic core exercise groups on dynamic balance, spinal stability, and hip mobility in young female office worker. In addition, no meta-analysis study has been found comparing the effects of both types of core exercises.

The purpose of this study was to compare the effects of 12-week online-delivered isometric and dynamic core stability exercises on functional movements, dynamic postural control, and core endurance in healthy young adults.

We hypothesized that the isometric core exercise (ICE) and dynamic core exercise (DCE) groups would show significant improvements in functional movement, dynamic postural control, and core endurance compared with the control group and that the effects on variables would show significant differences between the ICE and DCE groups.

Methods

Participants

In this single-blind randomized controlled trial, the researchers who performed the pre- and post-tests were blinded to the group assignments. The required sample size for the analysis was 39 (13 for each group), which was calculated using G*Power software (version 3.1.9.7; University of Kiel, Germany), for the two-way repeated measures analysis of variance (ANOVA), with an alpha level of 0.05, a power of 0.90, and an effect size of 0.60 (Cohen's d). The effect size was referred to the results of a previous study of the effects of 6-week core stability exercises on the YBT in horse riders [27]. However, the drop-out rate was predicted to be approximately 30%, and 60 participants were recruited.

Sixty young adults (age range: 19-34 years; 12 males, 48 females) participated in this study. They were either undergraduate or graduate students. The participants comprised 58 Korean students and two Asian international female students (1 Chinese and 1 Japanese). This study is a parallel group design in which each participant is randomized to one of three groups. They were randomly assigned to the ICE, DCE, or control group evenly according to the group assignment number selected by participants from the opaque box after the pre-test <Figure 1>. However, in order to evenly distribute gender, boxes were classified according to gender.

Inclusion criteria for participation were as follows: (1) adults aged 19–35 years and (2) persons who had not performed core exercises (e.g., abdominal and back exercises such as plank and back extension) in the past year. Exclusion

Table 1. Demographic characteristics of the participants.*

Variable	ICE (N=16, 4 males)	DCE (N=14, 3 males)	Control (N=19, 4 males)	p†
Age (years)	26.2 ± 4.2	27.4 ± 3.7	26.7 ± 3.8	0.691
Height (cm)	165.6 ± 10.2	164.2 ± 8.7	164.2 ± 5.6	0.854
Weight (kg)	56.9 ± 9.3	62.7 ± 17.5	59.9 ± 11.2	0.467
Body mass index (kg/m^2)	20.6 ± 1.7	22.8 ± 4.5	22.1 ± 3.3	0.162

*ICE, isometric core exercise group; DCE, dynamic core exercise group; Control, control group. Values are presented as mean ± standard deviation.
†No significant differences between groups; *p* values using one-way analysis of variance.

criteria for participation were as follows: (1) persons who had been treated for musculoskeletal injuries within the last 6 months, (2) persons who had been restricted from participating in sports or daily living activities for more than a week due to musculoskeletal injuries within the last 6 months, (3) persons who had pain in joints such as the neck, shoulder, lower back, ankle, and knee during active movement, and (4) persons who had experienced musculoskeletal surgery within the last 3 years. Drop-out criteria were as follows: (1) persons who withdrew consent to participate in this study and (2) persons with a participation rate of less than 70%.

All participants provided written informed consent, which was approved by the Institutional Review Board (No.2106/004-020), before study participation. After the 12-week exercise intervention period, 11 out of the 60 participants dropped out. The participants' demographic characteristics are summarized in <Table 1>.

Measurement Procedures

Three core endurance tests developed by McGill et al. [7] were used to examine core muscle endurance. These tests consisted of three positions: trunk flexor endurance test, trunk lateral (right or left) endurance test, and trunk extensor endurance test.

The trunk flexor endurance test required the participants to sit on the mat and place the trunk against a board with an angle of 60° from the mat. The inclination angle was set using an electronic gradient meter attached to the board. Both the knee and hip joints were flexed to 90°, and the hands were placed on the opposite shoulder. The feet were placed shoulder-width apart on the mat, and no equipment was used to stabilize the feet.

The trunk lateral endurance test required the participants to lay on the mat on their preferred side (right or left) with extended legs. The reason for measuring only one side was that it was considered that if both sides were measured, the first side could affect the results of the other side. The upper foot was placed in front of the lower foot (heel to toe position). The lower arm was flexed to 90°, and the elbow was placed under the shoulder. The upper hand was placed on the opposite shoulder, and the hips were lifted to maintain a straight line over their whole body.

The trunk extensor endurance test required the participants to be in a prone position, positioning the anterior superior iliac spine at the edge of the table. The hands were placed on the opposite shoulder, and the whole body was kept parallel to the floor. In order to stabilize the legs, the measurement assistant pressed the participant's calf with both hands.

The participants were encouraged to maintain each test position as long as possible. All tests recorded the maximum static holding time (seconds) with the correct posture in each position. Before and after the core endurance tests, all participants performed stretching exercises focused on the abdominal and lower back muscles.

The YBT-UQ and YBT-LQ were used to examine dynamic postural control. The YBT-LQ was used to measure the ability to maintain single-leg stance while the opposite leg reaches as far as possible in the anterior (ANT), posteromedial (PM), and posterolateral (PL) directions. Before the test trials, the participants performed five practice trials on the ground, and one practice trial on the test kit in order not to be affected by the learning effect. After performing the practice trials, the participants performed three test trials in each direction.

The composite score of the YBT-LQ was obtained by the sum of the greatest reach (cm) in each direction (ANT, PM, PL) divided by 3 times the length of the right leg (the distance from the anterior superior iliac spine to the medial malleolus in supine position on a table or mat) multiplied by 100 [28].

The YBT-UQ was used to measure the ability to maintain single-arm front support while the opposite arm reaches as far as possible in medial, inferolateral (IL), and superolateral (SL) directions. It requires upper-extremity stability (stance side) and mobility (reaching side) and core stability to maintain dynamic postural control in a closed kinetic chain position [29].

Before the test trials, the participants performed one practice trial on the test kit to prevent fatigue. The participants then performed three test trials in all directions. Participants' dynamic postural control ability was measured using the YBT test kit (Functional Movement Systems Inc., Chatham, Virginia, USA).

The composite score of the YBT-UQ was obtained by the sum of the greatest reach (cm) in each direction (medial, IL, SL) divided by 3 times the length of the right arm (the distance from the cervical 7 spinous process to the end of the third finger with the arm abducted to 90°) multiplied by 100 [28].

The mean value of right and left sides of the YBT-UQ and YBT-LQ was used for analysis.

The FMS was used to examine functional movement. It consists of seven functional movements that require a balance of mobility and stability: deep squat (DS), hurdle step (HS), in-line lunge (ILL), shoulder mobility (SM), active straight leg raise (ASLR), trunk stability push-up (TSPU), rotary stability (RS). Each movement was scored 0–3, and if both sides were tested, the lowest side score was used [11, 12]. A score of 3 indicates that the participant performed a functional movement without compensatory movement. A score of 2 indicates that the participant performed a functional movement with some degree of compensatory movement. A score of 1 indicates that the participant was unable to perform or complete a functional movement. A score of 0 indicates that the participant had pain while performing a functional movement or a clearing test (pain provocation test). All participants reported no pain while performing the seven functional movements and three clearing tests [12] (shoulder clearing, spinal extension clearing, and spinal flexion clearing tests).

The participants performed three test trials per functional movement. It was measured using the FMS test kit (Functional Movement Systems Inc., Chatham, Virginia, USA).

The tests were conducted in the following order: (1) FMS, (2) YBT-LQ, (3) YBT-UQ, (4) trunk flexor endurance test, (5) trunk lateral endurance test, and (6) trunk extensor endurance test. The required time for all tests was approximately an hour. Approximately 5–10 s was given between each trial in the FMS and YBT, and 1–2 min of rest with stretching exercises focused on the abdominal and lower back muscles was given between core endurance tests.

Five testers participated in this study. The FMS performed with shoes on, whereas the YBT-UQ, YBT-LQ, and core endurance tests were performed with shoes off. All testers completed an FMS level 1 certification for measurement methods, and two of testers held a physical therapist license in South Korea. Two testers completed a YBT certification for measurement methods, and they shared the YBT test manual with other three testers and practiced together several times. All measurements were conducted in a face-to-face manner in a university laboratory. Pre-test was conducted within 2 weeks before the start of exercise intervention, and post-test was conducted within 2 weeks after the end of exercise intervention.

Intervention Methods

Participants in the ICE and DCE groups performed 40-60 min real-time online-delivered core exercise session via Zoom video conferencing application, twice a week for 12 weeks. The exercise sessions were conducted in the order of 5-10 min of warm-up, 30-40 min of core exercises, and 5-10 min of cool-down. The warm-up and cool-down exercises were composed of stretching exercises focused on the abdominal and lower back muscles. Participants in the control group did not participate in exercise intervention.

The ICE program consisted of five exercises, namely, modified curl-up, bird-dog, side bridge, plank, and supine bridge (or single leg supine bridge) <Figure 2>. The DCE program was composed of five exercises including crunch, back extension, side crunch, dynamic supine bridge (or single leg dynamic supine bridge), and leg raise (both legs) <Figure 3>. Of the five exercises, two exercises mainly stim-

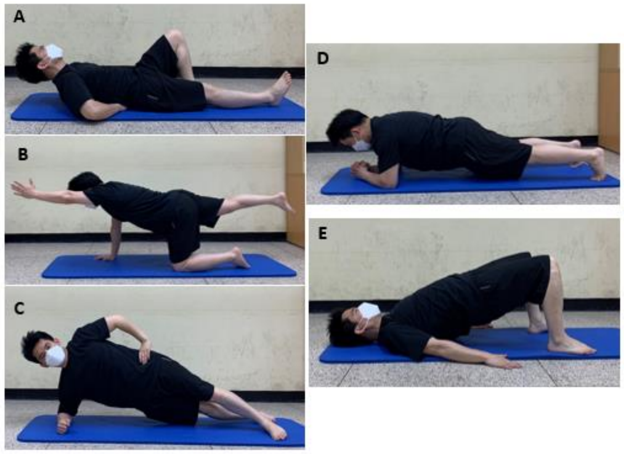

Figure 2. Isometric core exercises. (A) Modified curl-up, (B) Bird-dog, (C) Side bridge, (D) Plank, (E) Supine bridge.

Figure 3. Dynamic core exercises. (A) Crunch, (B) Back extension, (C) Side crunch, (D) Dynamic supine bridge, (E) Leg raise.

Table 2. The program for isometric core exercise group.*

	Week 1 to 3	Week 4 to 6	Week 7 to 9	Week 10 to 12
Modified curl-up	Hold for 10 s 3 sets 3/2/1 reps/side(leg)	Hold for 10 s 3 sets 3/2/2 reps/side(leg)	Hold for 10 s 3 sets 3/3/2 reps/side(leg)	Hold for 10 s 3 sets 3/3/3 reps/side(leg)
	10 s rest between sets			
Bird-dog	Hold for 10 s 4 reps/side	Hold for 10 s 5 reps/side	Hold for 15 s 5 reps/side	Hold for 20 s 5 reps/side
	Perform alternately left and right side (cross crawl position) without rest			
Side bridge	Hold for 30 s /side 3 sets (Heel to toe)	Hold for 30 s /side 3 sets (Feet together)	Hold for 40 s /side 3 sets (Feet together)	Hold for 50 s /side 3 sets (Feet together)
	30 s rest between sets			
Plank	Hold for 30 s 3 reps	Hold for 40 s 3 reps	Hold for 50 s 3 reps	Hold for 60 s 3 reps
	30 s rest between sets			
Supine bridge	Hold for 40 s 3 reps	Hold for 50 s 3 reps	Hold for 60 s 3 reps	Hold for 20 s /side 3 reps (Single leg)
	30 s rest between sets			

*1 minute rest between exercises.

ulate the anterior part; two exercises, the posterior part; and one exercise, the lateral part of the core. The programs for the ICE and DCE are described in <Table 2> and <Table 3>, respectively. In order to increase the exercise intensity and volume, the holding time or number of repetitions (or sets) was increased every 3 weeks.

All sessions were conducted by a certified sports instructor who was not a researcher in this study. Feedback on the accuracy of the participants' movements was delivered in real time while looking at a screen on which the instructor could observe all the participants' movements.

A total of 24 exercise sessions were carried out for each group. If the participant could not participate in real-time online-delivered session due to personal reasons, they performed exercise while watching the recorded session of the exercise video uploaded on YouTube and then send an exercise photo to the researcher for confirmation. Participants with a participation rate of less than 70% (<17 sessions of the total) over the entire intervention period were considered dropped out. All participants were asked not to participate in

Table 3. The program for dynamic core exercise group.*

	Week 1 to 3	Week 4 to 6	Week 7 to 9	Week 10 to 12
Crunch	15 reps 3 sets	15 reps 4 sets	20 reps 4 sets	25 reps 4 sets
Back extension	12 reps 3 sets	12 reps 4 sets	15 reps 4 sets	20 reps 4 sets
Side crunch	10 reps/side 3 sets	10 reps/side 4 sets	12 reps/side 4 sets	15 reps/side 4 sets
Dynamic supine bridge	15 reps 3 sets	15 reps 4 sets	20 reps 4 sets	10 reps/side 4 sets (Single leg)
Leg raise	10 reps 3 sets	10 reps 4 sets	12 reps 4 sets	15 reps 4 sets

*30 seconds rest between sets, and 1 minute rest between exercises.

other exercises for 12 weeks.

Statistical Analysis

Descriptive data are presented as mean ± standard deviation. One-way ANOVA was used to examine baseline characteristics between groups. The effects of the online-delivered ICE and DCE on functional movement, dynamic postural control, and core endurance were analyzed using two-way (group-by-time) repeated measures ANOVA. The effect sizes (ES) are presented as partial eta squared. An ES of 0.01-0.06 was considered a small effect; 0.06-0.14, a medium effect; and >0.14, a large effect [30].

In the case of statistically significant group-by-time interaction effects, a contrast test was performed to identify the difference between groups. An alpha level of 0.05 was set as statistically significant for all tests, and all data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

Results

The results of the core endurance tests are presented in <Table 4>. Statistically significant group-by-time interaction

Table 4. Main and interaction effects of the core endurance tests.*

Variables	ICE			DCE			Control			p (ES)			Observed power
	Pre	Post	Mean difference (Post-pre)	Pre	Post	Mean difference (Post-pre)	Pre	Post	Mean difference (Post-pre)	Main effect: time	Main effect: group	Interaction effect : group X time	
Trunk flexor endurance test (seconds)	74.1± 59.0	185.4± 167.1	+111.3	70.0± 78.5	185.4± 123.9	+115.4	47.4± 44.1	54.5± 42.9	+7.1	**<0.001 (0.361)**	**0.006 (0.201)**	**0.006† (0.201)**	0.848
Trunk lateral endurance test (seconds)	49.4± 34.9	73.2± 26.2	+23.8	35.7± 10.4	60.4± 29.5	+24.7	26.7± 16.9	33.9± 20.2	+7.2	**<0.001 (0.448)**	**0.001 (0.280)**	**0.029‡ (0.143)**	0.669
Trunk extensor endurance test (seconds)	71.4± 52.3	120.5± 76.0	+49.1	95.1± 44.6	143.9± 61.2	+48.8	71.5± 47.3	80.8± 51.1	+9.3	**<0.001 (0.466)**	**0.075 (0.106)**	**0.005§ (0.206)**	0.858

*ICE, isometric core exercise group; DCE, dynamic core exercise group; Control, control group; ES, effect size (partial eta squared). Values are presented as mean ± standard deviation. Bold font indicates statistical significance (p<0.05); p values using two-way repeated measures analysis of variance.
†Significant differences between ICE and control (p=0.005, ES=0.162), DCE and control (p=0.008, ES=0.145).
‡Significant differences between ICE and control (p<0.001, ES=0.277), DCE and control (p=0.025, ES=0.105).
§Significant differences between DCE and control (p=0.024, ES=0.106).

Table 5. Main and interaction effects of the composite score of the YBT-UQ, YBT-LQ, and FMS.*

Variables	ICE			DCE			Control			p (ES)			Observed power
	Pre	Post	Mean difference (Post-pre)	Pre	Post	Mean difference (Post-pre)	Pre	Post	Mean difference (Post-pre)	Main effect: time	Main effect: group	Interaction effect : group X time	
YBT-UQ, (% upper limb length)	78.0±6.6	87.2±7.4	+9.2	77.8±9.1	85.5±11.0	+7.7	73.2±7.6	76.7±7.1	+3.5	**<0.001 (0.611)**	**0.009 (0.185)**	**0.010† (0.180)**	0.792
YBT-LQ, (% lower limb length)	95.5±5.5	100.6±5.4	+5.1	97.6±7.7	102.7±8.6	+5.1	94.9±6.6	96.6±6.1	+1.7	**<0.001 (0.348)**	0.130 (0.085)	0.134 (0.084)	0.409
FMS	14.13±1.82	15.75±1.65	+1.62	14.57±1.70	15.86±1.66	+1.29	13.74±1.85	13.79±2.02	+0.05	**<0.001 (0.304)**	**<0.029 (0.142)**	**0.010‡(0.183)**	0.801

*YBT-UQ, Y balance test upper quarter; YBT-LQ, Y balance test lower quarter; FMS, functional movement screen; ICE, isometric core exercise group; DCE, dynamic core exercise group; Control, control group; ES, effect size (partial eta squared). Values are presented as mean ± standard deviation. Bold font indicates statistical significance (*p*<0.05); *p* values using two-way repeated measures analysis of variance.
†Significant differences between ICE and control (p=0.005, ES=0.159), DCE and control (p=0.017, ES=0.118).
‡Significant differences between ICE and control (p=0.039, ES=0.089), DCE and control (p=0.015, ES=0.122).

Table 6. Comparison of the seven movements of the FMS between groups.*

	ICE			DCE			Control		
	Pre	Post	Mean difference (Post-Pre)	Pre	Post	Mean difference (Post-Pre)	Pre	Post	Mean difference (Post-Pre)
1. Deep squat	1.94±0.77	**2.38±0.62†**	+0.44	2.07±0.73	2.29±0.73	+0.22	2.00±0.75	1.95±0.85	-0.05
2. Hurdle step	2.06±0.25	2.13±0.34	+0.07	2.14±0.36	2.21±0.43	+0.07	2.16±0.38	2.00±0.33	-0.16
3. In-line lunge‡	2.56±0.51	**2.94±0.25†**	+0.38	2.57±0.51	**2.93±0.27†**	+0.36	2.37±0.50	2.47±0.51	+0.1
4. Shoulder mobility	2.88±0.34	2.94±0.25	+0.06	2.86±0.36	2.86±0.36	0	2.74±0.56	2.79±0.54	+0.05
5. Active straight leg raise	2.31±0.79	**2.56±0.63†**	+0.25	2.36±0.75	**2.64±0.63†**	+0.28	2.21±0.63	2.21±0.71	0
6. Trunk stability push-up	1.13±0.34	1.44±0.81	+0.31	1.21±0.58	1.43±0.76	+0.22	1.16±0.50	1.21±0.63	+0.05
7. Rotary stability	1.25±0.45	1.38±0.50	+0.13	1.36±0.50	1.50±0.52	+0.14	1.11±0.32	1.16±0.38	+0.05

*FMS, functional movement screen; ICE, isometric core exercise group; DCE, dynamic core exercise group; Control, control group. Values are presented as mean ± standard deviation. Bold font indicates statistical significance (*p*<0.05).
†Post-test value was significantly greater than pre-test within group by a paired t-test (*p*<0.05).
‡Significant differences between groups at the post-test by one-way analysis of variance; the ICE and DCE showed a significantly greater than the Control by the Scheffe's post hoc test (*p*<0.05).

effects were found on all core endurance tests. Compared with the control group, the ICE group showed a significantly greater increase in the trunk flexor endurance test (p=0.005, ES=0.162) and the trunk lateral endurance test (p<0.001, ES=0.277). The DCE group showed a significantly greater increase in the trunk flexor endurance test (p=0.008, ES=0.145), the trunk lateral endurance test (p=0.025, ES=0.105), and the trunk extensor endurance test (p=0.024, ES=0.106) than the control group. However, no significant differences were found in the core endurance tests between the ICE and DCE groups by contrast tests performed after two-way repeated measures ANOVA.

The results of the YBT-UQ and YBT-LQ composite scores are presented in <Table 5>. The YBT-UQ showed a statistically significant group-by-time interaction effect. Compared with the control group, the ICE and DCE groups showed a significantly greater increase in the composite score of the YBT-UQ (ICE: p=0.005, ES=0.159; DCE: p=0.017, ES=0.118). However, no significant group-by-time interaction effect was noted in the composite score of the YBT-LQ between groups.

The results of the FMS composite score are presented in <Table 5>. A statistically significant group-by-time interaction effect was found on the FMS composite score. Compared with the control group, the ICE and DCE groups showed a significantly greater improvement in the FMS composite score (ICE: p=0.039, ES=0.089; DCE: p=0.015, ES=0.122). However, no significant difference was noted between the ICE and DCE groups.

The seven functional movement scores for the pre-test and post-test are presented in <Table 6>. Paired t-test showed a significant improvement at DS, ILL, and ASLR ($p<0.05$) in the ICE group after the intervention period. In the DCE group, ILL and ASLR were significantly improved. However, no significant difference was observed in the control group.

At the pre-test and post-test, one-way ANOVA was conducted to identify the significant differences between groups in each movement score. No significant difference was identified at the pre-test. However, a statistically significant difference was found in ILL at the post-test. The Scheffe's post hoc test showed that the ICE and DCE groups had a significantly greater score in ILL than the control group.

Discussion

The results of this study showed significant improvement in core endurance, functional movement, and dynamic postural control of the upper body in the ICT and DCE groups compared with the control group. Except for the results of dynamic postural control of the lower body, these results were consistent with the hypothesis of this study. However, significant differences were not found between the ICE and DCE groups in all variables. Both exercises showed similar levels of effects on all variables.

Faries and Greenwood [6] suggested that low-load and long-lasting (approximately 30 to 45 seconds) training improves core endurance. The ICE and DCE used in this study can be regarded as low-load exercise because additional resistance or weight was not used. In addition, both types of exercises can be regarded as long-lasting exercise because the ICE lasts from 10 to 60 seconds depending on the exercise, and the DCE is a high repetition (10 to 25 reps) exercise which takes approximately 30 to 60 seconds. For these reasons, it is considered that both types of exercise had a similar effect on improving core endurance.

In the YBT-UQ, while supporting in one arm in a push-up position, the free arm should be reached as far as possible in three directions (medial, IL, SL) at a time without a break. Therefore, core stability is considered an important factor to maintain the balance of trunk in this position. Few studies have verified the effect of core stability exercise on the YBT-UQ in untrained healthy young adults. Westrick et al [22] demonstrated a significant correlation between the YBT-UQ composite score and core stability test (dominant side trunk lateral endurance test; p=0.04, r=0.38) in 30 healthy college students (24 males, 6 females). Orgun et al [26] indicated that the 6-week ICE and DCE are effective in improving dynamic postural control tested by using the YBT-UQ and YBT-LQ in 34 female office workers (mean age: 36.4±6.5 years). However, no statistically significant differences were found between the groups in dynamic postural control. Both exercises were conducted in a manner that progressively increased time of exercise per set over the intervention period, which is similar to the method used in this study. In this study, the ICE and DCE groups significantly increased core endurance, which may have affected the significant improvement of the YBT-UQ compared with the control group.

The YBT-LQ required proprioception, coordination, flexibility, muscle strength of the lower limb, and core stability to maintain dynamic postural control in single leg stance position [28]. Ahmed et al. [32] reported significant positive correlations between the YBT-LQ and core stability (r=0.460) measured using Stabilizer Pressure Biofeedback Unit (Chatanooga, Australia) in badminton players (36 males aged 21.19±1.95 years). Bagherian et al. [13] demonstrated that an 8-week core stability exercise program causes a significant group-by-time interactions ($p<0.001$) in three directions (ANT, PM, PL) of the YBT-LQ between the core stability exercise group (60 male college athletes) and control group (40 male college athletes). A recent systematic review and meta-analysis study showed that core exercise improves dynamic postural control in three directions (ANT, PM, PL) [20].

However, no significant group-by-time interaction effect was found in YBT-LQ composite score between groups in this study. Improvement in core endurance is considered to have a greater influence in the dynamic postural control of the UQ than the LQ.

Okada et al. [10] demonstrated no significant correlations between core stability measured using McGill's endurance tests and the individual components of the FMS in 28 healthy male and female subjects (aged 24.4±3.9 years). However, Bahiraei et al. [33] showed significant differences in core stability measured using McGill's endurance tests between ≤14 (45 males) and >14 (45 males) FMS composite score groups in male athletes (aged 16-21 years). The high FMS score group performed significantly higher in the trunk flexor and lateral endurance tests than the low FMS score group. Bagherian et al [13] found a significant group-by-time interactions in the FMS composite score between the core stability exercise group (60 males) and control group (40 males) after an 8-week intervention period in college athletes.

The results of this study showed significantly improved core muscle endurance after the 12-week intervention period in the ICE and DCE groups, and significantly different FMS composite score from that of the control group. Therefore, functional movement was considered to significantly increase due to the improvement of core stability in this study.

Johnson et al. [34] proposed that among the seven movements, the DS, TSP, and RS are specific methods to evaluate core stability in three planes of movement. However, no significant improvement was found in the TSP and RS in all three groups. Seven male participants (7 out of 11 males) scored 3 points, and no female (0 out of 38 females) participants scored 3 points in the TSP at the post-test. Only three female participants scored 2 points. Based on these results, upper body strength is considered to be a more important factor in the TSP than core stability in female young adults who participated in this study.

Summarizing the results of this study, both types of core exercises have been shown to be effective for core stability-related variables, so both exercises can be recommended for young adults. In addition, since the participants in this study were college students or graduate students who had a sedentary behavior for a long time, the frequency and duration of exercise at the level performed in this study (twice a week, within an hour per session, for 12 weeks) were given to those with a similar lifestyle can be recommended.

This study has some limitations. The differences in the effects of ICE and DCE on the variables by sex could not be analyzed because the number of male participants was too small. In addition, the amount of exercise was similarly adjusted based on the exercise time. However, whether the actual amount of exercise applied to the body was objectively similar between the ICE and DCE was unclear. In the case of different types of exercise, such as isometric and dynamic core exercises, the amount of exercise can be similarly set by measuring the same amount of time for which stimulation is applied to the corresponding muscle during exercise. All participants were asked not to participate in other exercises during the intervention period, but this could not be accurately measured. Further studies are needed to confirm these limitations.

Conclusion

The 12-week online-delivered isometric and dynamic core stability exercises were effective at improving core endurance, functional movement, and dynamic postural control of the upper body in healthy young adults. These results are consistent with the hypothesis of this study. However, no significant differences were found between the ICE and DCE groups in all variables. Therefore, both types of core exercises may be recommended for improving core stability, but further studies are needed.

References

1. Willson JD, Dougherty CP, Ireland ML, Davis IM. Core stability and its relationship to lower extremity function and injury. J Am Acad Orthop Surg. 2005; 13:316-25.
2. Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. Sports Med. 2006; 36(3):189-98.
3. Akuthota V, Ferreiro A, Moore T, Fredericson M. Core Stability Exercise Principles. Curr Sports Med Rep. 2008;

7(1):39-44.
4. McGill SM. Low back stability: from formal description to issues for performance and rehabilitation. Exerc Sport Sci Rev. 2001; 29(1):26-31.
5. Majewski-Schrage T, Evans TA, Ragan B. Development of a core-stability model: a Delphi approach. J Sport Rehabil. 2014; 23(2): 95-106.
6. Faries MD, Greenwood M. Core training: stabilising the confusion. Strength Cond J. 2007; 29(2):10-25.
7. McGill SM, Childs A, Liebenson C. Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. Arch Phys Med Rehabil. 1999; 80(8):941-4.
8. Saeterbakken AH, Fimland MS, Navarsete J, Kroken T, Van den tillaar R. Muscle Activity, and the Association between Core Strength, Core Endurance and Core Stability. J Nov Physiother Phys Rehabil. 2015; 2(2):28-34.
9. Santos MS, Behm DG, Barbado D, DeSantana JM, Da Silva-Grigoletto ME. Core Endurance Relationships with Athletic and Functional Performance in Inactive People. Front Physiol. 2019; 10:1490.
10. Okada T, Huxel KC, Nesser TW. Relationship between core stability, functional movement, and performance. J Strength Cond Res. 2011; 25(1):252-61.
11. Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: the use of fundamental movements as an assessment of function-part 1. Int J Sports Phys Ther. 2014; 9(3):396-409.
12. Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: the use of fundamental movements as an assessment of function-part 2. Int J Sports Phys Ther. 2014; 9(4):549-63.
13. Bagherian S, Ghasempoor K, Rahnama N, Wikstrom EA. The Effect of Core Stability Training on Functional Movement Patterns in College Athletes. J Sport Rehabil. 2019; 28(5):444-9.
14. Beardsley C, Contreras B. The functional movement screen: a review. Strength Cond J. 2014;36(5):72-80.
15. Pollock AS, Durward BR, Rowe PJ, Paul JP. What is balance? Clin rehabil. 2000; 14(4):402-6.
16. Johnston W, Dolan K, Reid N, Coughlan GF, Caufield B. Investigating the effects of maximal anaerobic fatigue on dynamic postural control using the Y-Balance Test. J Sci Med Sport. 2018; 21(1):103-8.
17. Chimera NJ, Smith CA, Warren M. Injury history, sex, and performance on the functional movement screen and Y balance test. J Athl Train. 2015; 50(5):475-85.
18. Stapleton DT, Boergers RJ, Rodriguez J, et al.. The relationship between functional movement, dynamic stability, and athletic performance assessments in baseball and softball athletes. J Strength Cond Res. 2021; 35(Suppl 12):s42-50.
19. Huxel Bliven KC, Anderson BE. Core stability training for injury prevention. Sports Health. 2013; 5(6):514-22.
20. Barrio ED, Ramirez-Campillo R, Garcia de Alcaraz Serrano A, Raquel Hernandez-García R. Effects of core training on dynamic balance stability: A systematic review and meta-analysis. J Sports Sci. 2022; 40(16):1815-23.
21. McGill S. Low back disorders: evidence-based prevention and rehabilitation, Third edition. Champaign, IL: Human Kinetics. 2015.
22. Leetun DT, Ireland ML, Willson JD, Ballantyne BT, Davis IM. Core stability measures as risk factors for lower extremity injury in athletes. Med Sci Sports Exerc. 2004; 36(6):926-34.
23. Silfies SP, Ebaugh D, Pontillo M, Butowicz CM. Critical review of the impact of core stability on upper extremity athletic injury and performance. Braz J Phys Ther. 2015; 19(5):360-8.
24. Suner-Keklik S, Numanoglu-Akbas A, Cobanoglu G, Kafa N, Guzel NA. An online pilates exercise program is effective on proprioception and core muscle endurance in a randomized controlled trial. Ir J Med Sci. 2022; 191(5):2133-9.
25. Saeterbakken AH, Loken E, Scott S, Hermans E, Vereide VA, Andersen V. Effects of ten weeks dynamic or isometric core training on climbing performance among highly trained climbers. PLoS One. 2018;13(10):e0203766.
26. Orgun E, Kurt C, Ozsu I. The effect of static and dynamic core exercises on dynamic balance, spinal stability, and hip mobility in female office workers. Turk J Phys Med Rehabil. 2020; 66(3):271-80.

27. Lam NHK, Lau WM, Lau TL. Effects of a 6-week core stabilization training program on dynamic balance and trunk stabilization endurance of horse riders. Sport Sci Health. 2021; 17:655-64.
28. Ruffe NJ, Sorce SR, Rosenthal MD, Rauh MJ. Lower quarter and upper quarter y balance tests as predictors of running-related injuries in high school cross-country runners. Int J Sports Phys Ther. 2019;14(5):695-706.
29. Myers H, Poletti M, Butler RJ. Difference in Functional Performance on the Upper-Quarter Y-Balance Test Between High School Baseball Players and Wrestlers. J Sport Rehabil. 2017; 26(3):253-9.
30. Cohen J. Statistical Power Analysis for the Behavioral Sciences. 2nd Edn. Lawrence Erlbaum, Mahwah, NJ. 1988.
31. Westrick RB, Miller JM, Carow SD, Gerber JP. Exploration of the Y-balance test for assessment of upper quarter closed kinetic chain performance. Int J Sports Phys Ther. 2012; 7(2):139-47.
32. Ahmed S, Saraswat A, Esht V. Correlation of core stability with balance, agility and upper limb power in badminton players: a cross-sectional study. Sport Sci Health. 2022; 18:165-169.
33. Bahiraei S, Sharbatzadeh R, Nouri M. Relationship between core stability and functional movement screening test in athlete. Trends Sport Sci. 2019; 3(26):129-35.
34. Johnson CD, Whitehead PN, Pletcher ER, Faherty, MS, Lovalekar, MT, Eagle, SR, Keenan, KA. The Relationship of Core Strength and Activation and Performance on Three Functional Movement Screens. J Strength Cond Res. 2018; 32(4):1166-73.