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Effects of a 7-week combined core stabilization exercise program on muscle contractile properties and function in adults with a sedentary lifestyle

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Purpose: The purpose of this study was to examine the effects of a combined core stabilization exercise program on the static contractile properties of the erector spinae and the isokinetic muscle function of trunk flexion and extension in office workers aged twenty years and older. *Methods*: All participants performed a combined core stabilization exercise program, for seven weeks. And all participants were assessed using tensiomyography to evaluate the contractile properties of the erector spinae, and also assessed for isokinetic trunk strength. *Results*: As a result of tensiomyography, we found that significant main effect of sex on contraction time ($p \leq 0.001$), and maximum radial displacement, velocity of contraction demonstrated significant main effects for sex and time ($p \leq 0.001$). Regarding isokinetic trunk muscle function, significant main effects of sex and time were observed for trunk flexion, extension, and the flexion/extension ratio at 60°/sec ($p \leq 0.001$) and 90°/sec ($p \leq 0.001$). In addition, trunk extension at 90°/sec demonstrated a significant sex-by-time interaction ($p = 0.010$). *Conclusions*: These findings suggest that overall, the 7-week combined core stabilization exercise program was effective in enhancing the static contractile properties of the erector spinae and improving trunk isokinetic muscle function.

Key words: *combined core stabilization exercise, sedentary lifestyle, static contractile properties, isokinetic muscle function*

1. Introduction

Physical inactivity has been reported to contribute to musculoskeletal disorders across various regions of the body, with a particularly strong association with the development of low back pain (LBP) [32], [39]. Prolonged sedentary behavior can lead to muscle weakness, which contributes to lumbar instability and substantially increases the risk of LBP [1], [33]. Both decreased levels of physical activity and prolonged sedentary lifestyles are closely related to the onset of LBP [1]. In individuals with chronic low back pain (CLBP) lasting more than 12 weeks, there is often a tendency to limit and minimize trunk movement in an effort to alleviate pain. This avoidance not only weakens trunk muscle strength and function, but also reduces overall physical activity, functional ability and work productivity. Such movement restriction can also be interpreted as a manifestation of fear-avoidance behavior, in which individuals avoid regular movement or changes in posture due to fear of pain [1].

Various interventions aimed at alleviating CLBP resulting from sedentary behavior and physical inactivity – such as non-surgical treatments, exercise, and metacognitive behavioral therapy – have been widely implemented and investigated in individuals with LBP [4], [24], [27]. A meta-analysis reported that performing stretching two to three times per week, especially when combined with aerobic or paraspinal strengthening exercises, effectively reduced pain intensity and lowered LBP incidence by approximately 30% [31]. These strength-

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ening exercises, particularly those targeting the muscles surrounding the spine, including the erector spinae, have been shown to not only alleviate localized pain but also stimulate angiogenesis, thereby enhancing muscle oxygen utilization and increasing blood flow [23]. Additionally, even in individuals with prolonged sedentary time, participation in high-intensity physical activity such as exercise has been associated with improvements in LBP symptoms [25]. Moreover, compared to general exercise programs, core stabilization exercises have been shown to improve core function and reduce pain more effectively in the short term among individuals with LBP [36].

Core stabilization exercise is an effective approach for strengthening the muscles surrounding the lumbar spine, pelvis and hip joints, as well as improving motor control, with a primary focus on enhancing lumbar stability [14]. Various studies have been conducted to verify its effects, including pre- and post-intervention assessments of pain-free active range of motion using an inclinometer (Angle/Level, Dejon Tool Co., Covington, OH, USA), comparisons of Oswestry disability index (ODI) and visual analog scale (VAS) scores [11], and ultrasound-based measurements of muscle thickness [9]. Although many studies have examined the effects of core stabilization exercises using outcome variables such as pain intensity and range of motion, there is a lack of research that quantitatively evaluates their effects on specific muscle groups and isokinetic muscle function. Prolonged sedentary behavior weakens neuromuscular activation and alters the mechanical characteristics of trunk muscles, thereby affecting their static contractile properties and isokinetic function and ultimately reducing spinal stability and increasing the risk of low back pain [12]. Furthermore, only a few studies have assessed both the quantitative and functional characteristics of skeletal muscles – such as static contractile properties and isokinetic muscle function – following core stabilization exercises using various props, including bodyweight stretching, resistance bands, and foam rollers.

Moreover, since exercise-induced adaptations in static contractile properties and isokinetic muscle function are known to differ between men and women [21], it is important to evaluate the effects of core stabilization exercise separately by sex.

Therefore, this study aims to examine the effects of a combined core stabilization exercise program on the static contractile properties of the erector spinae and the isokinetic muscle function of trunk flexion and extension in office workers aged twenty years and older with prolonged sedentary behavior and low physical activity levels, and to identify sex-based differences in the exercise's effectiveness, thereby providing foundational data for the development of personalized exercise programs in the future.

2. Materials and methods

2.1. Participants

The study recruited 80 office-workers (40 male and 40 female) aged ≥20 years who did not meet the World Health Organization's 2020 guideline of ≥150 minutes of moderate-intensity or ≥ 75 minutes of vigorous-intensity physical activity per week, had no regular exercise experience in the previous six months, and reported a sedentary lifestyle characterized by >7 hours of sitting per day. Individuals who had musculoskeletal or neurological disorders within the past three months, a recent history of surgery, or pain severe enough to prevent participation in the combined core stabilization exercise program were excluded. The study was conducted after receiving approval from the Institutional Review Board of Incheon National University

Table 1. Demographic information and physical activity of participants

Variables		Value			
		Male (n = 40)	Female (n = 40)	t	p
Participants	age [years]	27.50 ± 6.14	28.28 ± 5.91	–0.575	0.567
	height [cm]	175.10 ± 5.96	161.19 ± 5.63	10.968	≤0.000***
	weight [kg]	72.82 ± 7.62	59.45 ± 11.51	6.125	≤0.000***
Physical activity	vigorous-intensity [day/week]	0.80 ± 0.72	0.70 ± 0.85	0.565	0.573
	vigorous-intensity [min/day]	12.00 ± 11.81	8.50 ± 10.51	1.400	0.165
	moderate-intensity [day/week]	1.00 ± 0.75	0.93 ± 1.02	0.374	0.710
	moderate-intensity [min/day]	16.12 ± 33.15	16.53 ± 26.10	0.534	0.595
Sedentary	Sedentary time [hour/day]	8.46 ± 1.44	8.53 ± 1.15	–0.214	0.831

Note. Mean ± standard deviation, *** $p < 0.001$.

(INUIRB No. 7007971-202012-003A). All participants gave written informed consent after receiving a full explanation of the study objectives and procedures.

To compare the physical characteristics, physical activity levels, and sedentary time between the male and female groups participating in this study, an independent-samples *t*-test was conducted. The participants' physical characteristics are presented in Table 1. As a result, significant gender differences were observed in physical characteristics: height ($t = 10.968$, $p < 0.000$) and weight ($t = 6.125$, $p < 0.000$). However, no significant differences were found in age, physical activity levels, or sedentary time (Table 1).

3. Measurements

3.1. Tensiomyography

To evaluate the mechanical properties of the erector spinae and its neuromuscular function, Tensiomyography (TMG; TMG-100 System electrostimulator, Slovenia) was used (Fig. 1). Before the measurements, caffeine intake, exercises that could induce fatigue, and other factors that might affect the procedure were restricted [3]. In addition, measurements were conducted after a five-minute rest to ensure the erector spinae remained relaxed. During the measurement, participants were positioned prone with a cushion placed under the anterior superior iliac spine (ASIS) to minimize lumbar lordosis, ensuring postural stability and reducing positional variability of the TMG sensor (GK40, Panoptik d.o.o., Ljubljana, Slovenia) placed on the surface of the erector spinae. A cushion was placed under the ankle joint to maintain approximately 5° of knee flexion. To measure displacement of the erector spinae, a digital displacement sensor (Dc–Dc Trans-Tek®, GK 40, Ljubljana, Slovenia) incorporating a spring with a stiffness of 0.17 N·mm^{-1} was used. Following Perotto et al. [26], the sensor location was marked with a water-based pen on the muscle belly at the anatomical site of the erector spinae, and, considering the maximum radial displacement (D_m) of 15 mm, the digital displacement sensor was positioned vertically. The electrode pads were attached with the proximal side serving as the anode (+) pad and the distal side as the cathode (–) pad, positioned symmetrically 5 cm apart on either side of the sensor. Single electrical stimulation began at 20 mA and was gradually increased in 20 mA increments until maximum displacement was reached. To minimize muscle fatigue during measurements, the rest period was set to 15 seconds, and to ensure the reliability of the assessments, all measurements were conducted by a single researcher.

Fig. 1. Tensiomyography device and appropriate supine position

3.2. Isokinetic trunk strength test

In this study, the isokinetic muscle function of trunk flexion and extension was measured using the Humac Norm Testing and Rehabilitation system (CSMi Medical & Solution, Stoughton, MA, USA) [29]. Before the measurements, an approximately five-minute dynamic stretching warm-up was conducted, and the measurement movements were thoroughly explained. Afterwards, drawing on previous studies, we prepared for

Fig. 2. Measurement of isokinetic trunk strength

the measurements and encouraged participants to perform at their maximum capacity [13]. Measurements were performed five times at an angular velocity of 60°/s and fifteen times at 90°/s, with approximately three minutes of rest between measurements to minimize muscle fatigue. During all measurements, participants were not encouraged or motivated, and all measurements were performed by a single evaluator.

3.3. Combined core stabilization exercise program

The combined core stabilization exercise program, based on the ACSM Position Stands (2011), consisted of sixty-minute sessions performed three times per week for a total of seven weeks [6], [28]. The warm-up in the program consisted of self-myofascial release of the thighs and posterior chain using a foam roller and lower-limb stretching exercises using a stretch band to relax muscles and fascia. The main exercise program was designed as a core stabilization routine aimed at improving core muscular endurance, coordination, proprioceptive function, and overall stability. The core stabilization component of the program was structured based on previous studies [34], During each exercise, participants were instructed to maintain the contraction for about 5 seconds and then relax for about 5 seconds, and detailed guidelines for the three exercise types are provided in Table 2.

Table 2. Combined core stabilization exercise program

Classification	Exercise Type	Exercise	Intensity	Time
Warm-up	Self-myofascial release (Foam roller)	Quadriceps rolling Hamstring rolling Gluteus rolling Lower back rolling Upper back rolling	Pain-free range 20 sec / 1 set Total 3 set	20 min
	Stretching (Band)	Quadriceps stretching Hamstring stretching Gluteus stretching Iliopsoas stretching		
Work out	Core stabilization exercise	Cat-camel Bracing & Hollowing Hip Bridge Bird dog Plank (side & prone) Back Extension	1 rep (5 sec contraction 5 sec relaxation) 20 reps / 1 set Total 3 sets	40 min

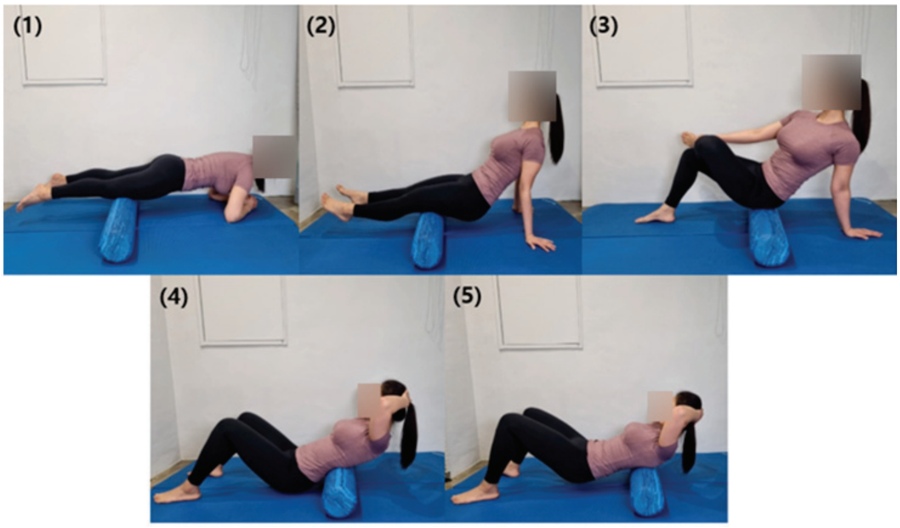

Fig. 3. Self-myofascial release (use foam roller). Caption: (1) Quadriceps rolling: Place the foam roller at the midpoint of the quadriceps, apply pressure, and roll; (2) Hamstring rolling: Place the foam roller at the midpoint of the hamstrings, apply pressure, and roll; (3) Gluteus rolling: Apply pressure with the foam roller over the entire gluteal region and roll; (4) Lower back rolling: Apply pressure with the foam roller over the entire lumbar region and roll; (5) Upper back rolling: Apply pressure with the foam roller over the entire thoracic region and roll

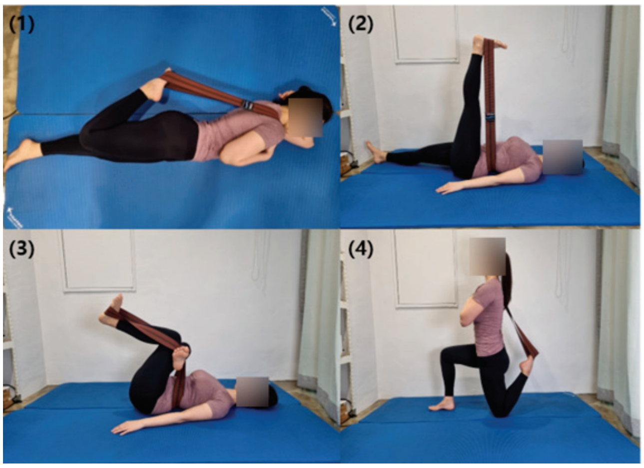

Fig. 4. Stretching (use band). Caption: (1) Quadriceps stretching: In a side-lying position, hook the band around the dorsum of the rear foot, loop it over the ipsilateral shoulder, and pull to stretch the quadriceps; (2) Hamstring stretching: In a supine position, anchor the band around the lumbar region and the arch of the foot to be stretched, flex the hip, and extend the knee to stretch the hamstring; (3) Gluteus stretching: From the hamstring stretch position, place the opposite ankle between the band and the thigh, flex the knee, and pull to stretch the gluteal muscles; (4) Iliopsoas stretching: In a lunge position, hook the band around the dorsum of the rear foot, drape it over the same-side shoulder, and pull while further flexing the same-side knee to stretch the iliopsoas

3.4. Data analysis

3.4.1. Analysis of contractile properties of erector spinae

To analyze the static contractile properties of the erector spinae, we used two variables with the highest intra-class correlation coefficients (ICC) for test–retest and intra-rater reliability: D_m (maximum radial displacement, 0.91–0.99), which records the muscle's maximal contraction displacement, and T_c (contraction time, 0.70–0.98), the time it takes the muscle to contract from 10% to 90% of that displacement [19]. Additionally, because T_c can be affected by the magnitude of D_m, the mechanical property results provided by the TMG were integrated concurrently to compensate, and the V_c, which is sensitive to changes in muscle force and associated with fatigue, was calculated and used according to Eq. (1) [15], [17]. For every measurement variable, the values from the right and left sides were summed and analyzed as averages.

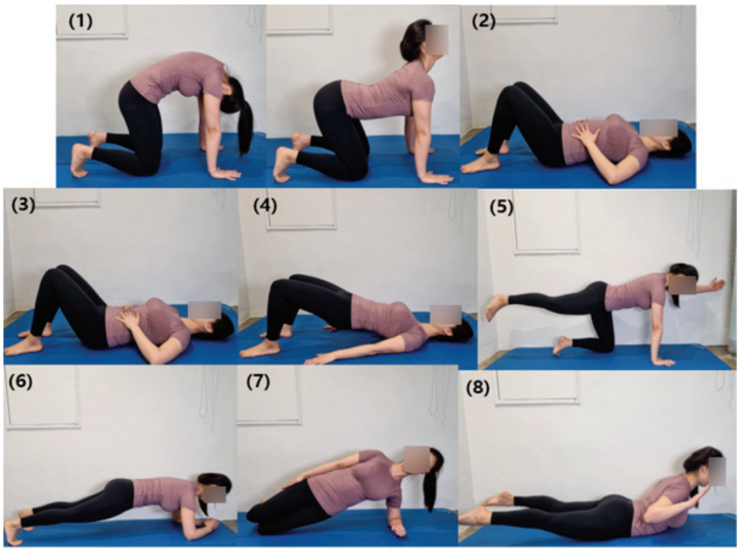

Fig. 5. Core stabilization exercise. Caption: (1) Cat–Camel: While kneeling on a mat with the knees flexed and the hands placed shoulder-width apart directly under the shoulders, inhale and sequentially extend the lumbar, thoracic, and cervical spine; then exhale and sequentially flex the cervical, thoracic, and lumbar spine; (2) Bracing: In a supine hook-lying position, inhale and expand the abdomen to induce a global contraction of the abdominal muscles; (3) Hollowing: In a supine hook-lying position, exhale while pulling the navel toward the lumbar spine to activate the deep abdominal muscle, the transversus abdominis; (4) Hip bridge: In a supine hook-lying position, exhale while lifting the hips, then inhale as you return to the starting position, engaging the core muscles throughout; (5) Bird dog: While kneeling on a mat with the knees flexed and hands placed shoulder-width apart directly under the shoulders, exhale while flexing the one shoulder and extending the opposite hip joint to engaging the core muscles; (6) Plank (front): In a prone position, flex the shoulders and elbows to 90 degrees, form a straight line from head to toe and maintain a neutral position of the scapulae and spine, engaging the core muscles; (7) Plank (side): In a side-lying position, flex the elbow to 90 degrees directly under the shoulder, form a straight line from head to toe and maintain a neutral alignment of the scapulae and spine, engaging the core muscles; (8) Back extension: In a prone position, exhale while extending the trunk and hip joints to engage the posterior core muscles.

$$V_c\,(\text{mm/ms}) = \frac{D_m}{T_c + T_d}\,. \tag{1}$$

3.4.2. Analysis of isokinetic muscle function of the trunk

In this study, to calculate precise isokinetic trunk muscle function, the relative strength value (% BW), which was adjusted for each participant's body weight, was derived from the peak torque (N_m) using Eq. (2) [37]. Additionally, to assess the strength ratio between trunk flexor and extensor, the flexor-to-extensor strength ratio (F/E ratio) was calculated using Eq. (3) below.

$$\text{BW}(\%) = \frac{\text{Peak Torque}}{\text{Body Weight}}\,, \tag{2}$$

$$\text{Ratio}(\%) = \frac{\text{Flexor value}}{\text{Extensor vslue}} \times 100\,. \tag{3}$$

3.5. Statistical analysis

An *a priori* power analysis using G*Power 3.1.9.7 indicated that 26 participants were required ($d = 0.80$, $\alpha = 0.05$, power = 0.80); therefore, the final sample size of 80 was more than sufficient. All variables collected from the participants were expressed as mean ± standard deviation (Mean ± SD). An independent-samples *t*-test was performed to compare participant characteristics between the male and female groups. To compare sex differences and pre-to-post changes in muscle contraction characteristics and isokinetic strength following the 7-week combined core stabilization exercise program, a linear mixed model (LMM) was used, with measurement time point (pre/post), sex, and their interaction specified as fixed effects. To control for individual differences among participants, the participants themselves were included as a random effect. Covariates comprised the pre-test values of each dependent variable, height, and weight, thereby adjusting for the influence of body stature and baseline measurements on the analysis. Model estimation was performed using restricted maximum likelihood (REML), and the significance of fixed effects was tested using *F*-statistics. Bonferroni post-hoc tests were performed for fixed effects found to be significant. Additionally, paired *t*-tests were conducted to compare changes in isokinetic flexion and extension strength before and after the combined core stabilization exercise program for all participants. All statistical significance levels were set at $p = 0.05$. All data collected in this study were analyzed using SPSS for Windows (ver. 28.0, IBM Corp., Armonk, NY, USA).

4. Results

4.1. Results of differences in contractile properties of erector spinae

The linear mixed-model analysis of the erector spinae's static contractile properties between male and female groups following the combined core stabilization exercise program showed a significant main effect of sex for T_c ($F_{(1, 78)} = 15.341$, $p \leq .001$), whereas the main effect of measurement time point was not significant. For D_m, there was a significant main effect of sex ($F_{(1, 78)} = 28.914$, $p \leq 0.001$), and the main effect of measurement time point was also significant ($F_{(1, 78)} = 34.219$, $p \leq 0.001$). For V_c, the main effect of sex was significant ($F_{(1, 78)} = 31.166$, $p \leq 0.001$), and the main effect of measurement time point was also significant ($F_{(1, 78)} = 46.760$, $p < 0.001$). Across all variables, the interaction effect between measurement time point and sex was not statistically significant (Table 3).

Table 3. Results of the linear mixed model analysis for contractile properties

Variables	Time	Male (M ± SD)	Female (M ± SD)	Sex effect	Time effect	Time × sex interaction
T_c [ms]	pre	14.35 ± 1.68	15.65 ± 2.39	≤0.000***	0.653	0.611
	post	14.33 ± 1.32	15.87 ± 2.07			
D_m [mm]	pre	4.37 ± 2.34	2.29 ± 1.12	≤0.000***	≤0.000***	0.653
	post	5.04 ± 2.16	3.07 ± 1.09			
V_c [mm/ms]	pre	0.13 ± 0.07	0.07 ± 0.03	≤0.000***	≤0.000***	0.955
	post	0.15 ± 0.06	0.09 ± 0.03			

Note. Mean ± standard deviation, *** $p < 0.001$.
Abbreviations: T_c – contraction time, D_m – maximum radial displacement, V_c – velocity of contraction for 90 seconds.

4.2. Results of differences in isokinetic muscle function of trunk

A linear mixed-model analysis of isokinetic trunk flexion and extension muscle function in a male and female group that underwent a core stabilization exercise program was conducted. At the 60°/sec measurement speed, significant main effects of sex and measurement time point were observed for isokinetic trunk flexion strength (sex effect, $F_{(1, 78)} = 45.349$, $p \leq .001$, time effect, $F_{(1, 78)} = 24.437$, $p \leq 0.001$), extension strength (sex effect, $F_{(1, 78)} = 65.132$, $p \leq .001$, time effect, $F_{(1, 78)} = 84.496$, $p \leq 0.001$), and the flexor-to-extensor ratio (sex effect, $F_{(1, 78)} = 21.481$, $p \leq 0.001$, time effect, $F_{(1, 78)} = 21.846$, $p \leq 0.001$) (Table 4).

At the 90°/sec measurement speed, significant main effects of sex and measurement time were observed for isokinetic trunk flexion strength (sex effect, $F_{(1, 78)} = 24.479$, $p \leq 0.001$, time effect, $F_{(1, 78)} = 22.345$, $p \leq 0.001$). For trunk extension strength (sex effect, $F_{(1, 78)} = 52.195$, $p \leq 0.001$, time effect, $F_{(1, 78)} = 79.440$, $p \leq 0.001$, interaction, $F_{(1, 78)} = 6.877$, $p = 0.010$) significant main effects of sex and measurement time point, as well as a significant interaction between sex and measurement time point, were found. For the ratio (sex effect, $F_{(1, 78)} =10.240$, $p = 0.002$, time effect, $F_{(1, 78)} = 31.005$, $p \leq 0.001$) significant main effects of both sex and measurement time point were found (Table 4).

The paired *t*-test comparing changes in trunk flexion and extension strength for all participants after the combined core stabilization exercise program showed that at 60°/sec measurement speed, the increase in trunk extension strength was significantly greater than that in flexion strength ($t = –4.362$, $p < 0.01$), and at 90°/sec measurement speed, the increase in extension strength was again significantly greater than that in flexion strength ($t = –5.586$, $p < 0.01$) (Table 5).

5. Discussion

This study aimed to investigate the effects of a 7-week combined core stabilization exercise program on the static contractile properties of the erector spinae and the isokinetic muscle function of trunk flexion and extension, as well as to examine sex-based differences in the exercise's effectiveness, in adult male and female office workers aged twenty years and older with prolonged sedentary behavior and low physical activity levels. The results for static contractile properties showed a significant main effect of sex on T_c ($p \leq 0.001$), while no significant effect was found across

Table 4. Results of the linear mixed model analysis for isokinetic muscle function of trunk [%]

Degree/sec	Variables	Time	Male (M ± SD)	Female (M ± SD)	Sex effect	Time effect	Time × sex interaction
60°/sec	flexion	pre	272.50 ± 57.78	216.43 ± 42.46	0.001***	0.001***	0.712
		post	297.78 ± 40.23	245.80 ± 28.86			
	extension	pre	257.50 ± 90.46	155.13 ± 51.71	0.001***	0.001***	0.116
		post	324.78 ± 73.02	202.58 ± 49.13			
	ratio	pre	115.88 ± 44.77	150.20 ± 42.78	0.001***	0.001***	0.781
		post	96.20 ± 26.57	128.03 ± 33.73			
90°/sec	flexion	pre	259.03 ± 60.08	216.10 ±40.79	0.001***	0.001***	0.716
		post	284.68 ± 46.67	238.08 ± 33.58			
	extension	pre	211.73 ± 82.09	143.23 ± 47.57	0.001***	0.001***	0.010*
		post	283.15 ± 58.37	182.18 ± 40.79			
	ratio	pre	140.80 ± 65.24	166.18 ± 58.98	0.001***	0.002**	0.546
		post	103.93 ± 26.00	136.55 ± 31.80			

Note. Mean ± standard deviation, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 5. Results of the paired *t*-test for pre-post changes in isokinetic muscle function of trunk [%]

Degree/sec	ΔFL	ΔEX	*t*	*P*
60°/sec	27.33 ± 49.17	57.36 ± 56.35	–4.36	0.01**
90°/sec	23.81 ± 44.81	55.19 ± 57.40	–5.59	0.01**

Note. Mean ± standard deviation, ** $p < 0.01$; Abbreviations: FL – flexion, EX – extension, Δ – change from pre-post intervention.

measurement time points; however, both D_m and V_c demonstrated significant main effects for sex and time ($p \leq 0.001$). Regarding isokinetic trunk muscle function, significant main effects of sex and time were observed for trunk flexion, extension, and the flexion/extension ratio at 60°/sec ($p \leq 0.001$). At 90°/sec, trunk flexion also showed significant main effects for sex and time ($p \leq 0.001$), and trunk extension exhibited significant main effects for both sex and time ($p \leq 0.001$), as well as a significant sex-by-time interaction ($p = 0.010$).

Following the combined core stabilization exercise program, a linear mixed model analysis of the static contractile properties of the erector spinae revealed that males exhibited significantly lower T_c values than females. T_c is known to vary depending on muscle fiber type composition, with higher proportions of type I fibers associated with increased T_c values, and higher proportions of type II fibers associated with decreased T_c values [12]. Previous studies have reported that females tend to have a higher proportion of type I fibers, whereas males generally exhibit a higher proportion of type II fibers [22], which may explain the significant main effect of sex observed in T_c in the present study. However, as muscle fiber type conversion through exercise is limited and temporal changes in fiber type remain unclear, it is likely that no significant time-dependent effects were observed [12].

In terms of D_m, which reflects muscle contractile displacement and serves as an indicator of muscle contractile strength, males demonstrated significantly greater values than females ($p \leq 0.001$). This is likely due to higher muscle density and larger cross-sectional area of the erector spinae in males, resulting in greater displacement during TMG-induced electrical stimulation [16]. Moreover, D_m values – negatively correlated with muscle stiffness – significantly increased following the intervention. The 7-week combined core stabilization exercise program, comprising self-myofascial release with foam rollers, stretching with resistance bands, and core stabilization exercises, likely reduced muscle stiffness and improved contractile properties of the erector spinae, thereby contributing to the observed increase in D_m [12].

Regarding V_c, which reflects the velocity of muscle contraction, males showed significantly higher values than females. This finding may be attributed to the combination of lower T_c and higher D_m values in males. Furthermore, the combined intervention likely enhanced erector spinae activation and increased motor unit recruitment, which contributed to the improvement in contraction velocity, as reflected by the significant increase in V_c [10], [30]. Accordingly, the increases in D_m and V_c observed after the 7-week combined core stabilization exercise program suggest improvements in muscle stiffness, contractile properties, and contraction velocity that reflect enhanced neuromuscular activation and may contribute to greater spinal stability and the prevention of low back pain [12].

In general, isokinetic muscle function at lower angular velocities such as 60°/sec is used to evaluate muscular strength and explosive force through slower contractions, while higher velocities like 90°/sec are used to assess muscular power and endurance through faster contractions [38]. In this study, males showed significantly higher trunk isokinetic strength than females when normalized by body weight, likely due to greater overall muscle strength in males, including in the trunk region [2]. Significant main effects across time points in trunk flexion and extension strength at both 60°/sec and 90°/sec suggest that the combined core stabilization exercise program contributed to improved trunk function in both sexes. Interestingly, trunk extension strength improved significantly more than flexion strength at both velocities in both men and women, which may be attributed to the program's structure. Self-myofascial release likely enhanced trunk mobility and enabled more effective activation of the extensor muscles [8], while exercises such as the hip bridge, bird-dog, and back extension likely improved neuromuscular coordination and strength in the trunk extensors [7].

A post-hoc analysis of the significant sex-by-time interaction for trunk extension strength at 90°/sec revealed that males improved by 71.42% from pre- to post-intervention, while females improved by 38.95%, suggesting a stronger response to the program in males. This may be due to sex-related differences in muscle cross-sectional area and fiber composition [22]. Regarding the trunk flexion-to-extension strength ratio at 60°/sec and 90°/sec, females showed significantly higher ratios than males ($p \leq 0.001$), consistent with their relatively higher normalized trunk flexion strength [35]. While the normal ratio in healthy adults is generally below 1.0 [5], [20], both sexes showed pre-intervention ratios above 1.0, indicating dominance of trunk flexor strength. This imbalance may result from prolonged sedentary behavior, which can lead to shortening and weakening of posterior trunk muscles, particularly stiffness in the lumbar extensors [18]. The significant time effect observed in the flexion-to-extension ratio at both velocities suggests that the intervention improved trunk extensor function in both sexes, moving the ratio closer to the normative range. Overall, the 7-week combined core stabilization exercise program, improvements in the isokinetic muscle function of the trunk flexors and extensors (strength, power, endurance) were observed, which may enhance lumbar stability through better motor control and thereby contribute to a reduced risk of low back pain [14], [33].

This study has several limitations. First, the seven-week intervention period was relatively short, making it difficult to evaluate long-term adaptations. Second, the participants were relatively young adults, which may limit the generalizability of the findings to older populations.

6. Conclusions

This study aimed to examine the effects of a 7-week combined core stabilization exercise program on the static contractile properties of the erector spinae and the isokinetic muscle function of trunk flexion and extension, as well as to compare gender-based differences in these effects among male and female office workers aged twenty years and older with prolonged sedentary behavior and low physical activity levels. The results showed that males had significantly lower T_c values but significantly higher D_m and V_c values compared to females, suggesting improvements in muscle stiffness, contractile strength, and contraction velocity following the combined core stabilization exercise program. In terms of trunk isokinetic muscle function, males exhibited significantly higher strength than females, likely due to baseline differences in muscle mass and strength; however, both genders demonstrated notable improvements after the combined core stabilization exercise program, with flexion-to-extension strength ratios approaching normal values. Moreover, trunk extension strength improved more than flexion strength in both genders, which may be attributed to the program's design, including self-myofascial release and exercises targeting the extensor muscles. Overall, the 7-week combined core stabilization exercise program was effective in enhancing the static contractile properties of the erector spinae and improving trunk isokinetic muscle function. This exercise program may also be feasibly implemented in clinical and workplace settings to enhance spinal health among sedentary individuals. Future research should investigate the effects of this exercise program in middle-aged and older adults with similar characteristics, such as prolonged sedentary behavior and low levels of physical activity.

Declaration of conflicting interests

The authors have no financial or personal relationships with other people or organizations that have inappropriately influenced this research.

Ethical approval and informed consent statements

This study was approved by the Institutional Review Board of the Incheon National University (INUIRB No. 7007971-202012-003A).

Data availability statement

Data are not publicly available due to privacy.

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