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Effects of Core Stabilization Exercise Programs on Changes in Erector Spinae Contractile Properties and Isokinetic Muscle Function of Adult Females with a Sedentary Lifestyle

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Abstract: This study aimed to investigate the effect of core stabilization exercises on the contractile properties and isokinetic muscle function of adult females with a sedentary lifestyle. We enrolled 105 adult females. Tensiomyography was performed on the erector spinae, and the isokinetic muscular functional test was performed on the trunk at an angular velocity of 60°/s and 90°/s. All participants performed the exercise for 60 min per day, 3 times a week, for 7 weeks. A Wilcoxon signed-rank test was performed at a significance level of 0.05. Tensiomyography (TMG) of the erector spinae revealed no significant post-exercise change in the contraction time; however, there was a significant post-exercise increase in the maximum radial displacement and mean velocity until 90% of the TMG was displaced. Additionally, the isokinetic muscular functional test of the trunk revealed a significant post-exercise increase in almost all variables. Our findings demonstrated that the core stabilization exercise reduced stiffness in the erector spinae, increased the velocity of erector spinae contraction, and effectively improved the isokinetic muscular function of the trunk.

Keywords: sedentary behavior; core stabilization training; neuromuscular properties; muscle function

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1. Introduction

There have been rapid changes in the physical, economic, and social environment in which modern-day people perform activities, which has contributed to a distinct decrease in physical activities [1]. The World Health Organization (WHO) recommends at least either 150 or 75 min of moderate- or high-intensity physical activity, respectively, or both to prevent reductions in physical activity levels [2]. The COVID-19 pandemic has caused many changes in our daily life, one of those is that physical activity level has decreased, whereas sedentary lifestyles have increased [3]. The resulting lack of physical activity and increasingly sedentary lifestyle can cause numerous physical problems; further, maintaining a sedentary lifestyle for >4 h a day can threaten health [4,5].

Functional decline caused by decreased physical activity, including muscle imbalance, muscle weakness, and loss of flexibility, can cause chronic musculoskeletal disorders [6]. Low-back pain is strongly associated with a sedentary lifestyle [7]; specifically, a more sedentary lifestyle is an independent risk factor for musculoskeletal disorders [8]. Further, a sedentary lifestyle is a risk factor for low-back pain since it can cause muscle fatigue, due to continued core muscle contractions, increased intradiscal loads, and the weakening of the posterior lumbar structure [9,10]. Kett et al. [8,11] reported increased lumbar muscle stiffness, as measured by an indentometer, after 4.5 h of sedentary work. Moreover, musculoskeletal disorders in the lower back may be caused by increased sedentary patterns since they increase muscle tension and sustain a shortened state in the lumbar region [8,11]. Additionally, a decreased spinal stabilization function due to the lumbar muscle weakening is a major cause of low-back pain [12,13]. Patients with low-back pain due to spinal instability have muscle tissue tension and damage due to the weakening of their lumbar extensors; accordingly, >85% of the total population experiences chronic low-back pain [14–16]. Previous studies have reported that women are more likely to be exposed to risk factors such as improper static posture [17], and the prevalence of low-back pain was higher in women than in men [18]. In women, it has been reported that there is a tendency to present worse and more persistent pain symptoms [19]. As aforementioned, increased tension and weakness in the trunk extensor resulting from a sedentary lifestyle can result in an increased incidence of low-back pain. Therefore, trunk-strengthening exercises are essential for reducing the incidence of low-back pain [9,11,14].

Patil and Mahajan [20] recently reported a significant improvement in core stability after prescribing a regular plank exercise for 6 weeks to 50 dentists who performed sedentary work for long hours. In a study on patients with non-specific low-back pain, Narouei et al. [21] reported that regular core stabilization exercise for 4 weeks could effectively increase muscle contractile thickness and reduce pain. Moreover, a study using a Swiss ball for 8 weeks reported a significant increase in core muscle activity after core stabilization exercises [22]. This broad range of benefits resulting from core stabilization can enhance exercise ability, prevent injuries, and alleviate low-back pain, which facilitates proper load balancing within the kinetic chain involving the spine and pelvis [23]. Therefore, systematic exercises for ensuring core stability are paramount for preventing a deterioration in trunk muscle function and low-back pain. However, previous studies on sedentary lifestyles have mostly focused on the physiological effects, including cardiovascular and metabolic effects, of lacking physical activities [24–27]. Moreover, few studies have applied systematic trunk exercise interventions for alleviating deteriorations in trunk muscle functions due to a sedentary lifestyle, with a concomitant assessment of the mechanical and neuromuscular properties of trunk muscles and the isokinetic muscle functions of the lumbar spine. Given the increasing amount of time spent sitting by modern-day people, there is a need for studies on appropriate exercise interventions for trunk stabilization that analyze the isokinetic muscle function of the lumbar spine and the mechanical and neuromuscular properties of trunk muscles.

Based on previous studies, muscle fatigue tends to decrease the time it takes to contract 10 to 90% of the maximum contractile displacement (contraction time (Tc)) [28]. With the strengthening of the trunk muscles through exercise, Tc is expected to increase due to the reduction in muscle fatigue. The results of a previous study analyzing the effect of the 3D moving platform exercise for 8 weeks did not show statistical significance, but based on the study results showing an increase in the maximum radial displacement (Dm) of the muscle, Dm is expected to increase through exercise [29]. In addition, based on previous studies, core stabilization exercise increases neuromuscular control by improving the sensory receptors and motor control of the core muscle [23]. Therefore, Vc90 is expected to increase through core stabilization exercise. Additionally, based on a previous study where the isokinetic muscle function of the lumbar region improved after 12 weeks of lumbar stabilization exercise [30], the isokinetic muscle function of the trunk will be improved through core stabilization exercise.

Therefore, the central purpose of this study is to propose basic data for facilitating the development of an effective core stabilization exercise program for preventing musculoskeletal disorders caused by a lengthy sedentary lifestyle. Specifically, we aimed to determine the effects of a 7-week core stabilization exercise program on the mechanical and neuromuscular properties of the erector spinae, including muscle stiffness, contraction velocity, contractile response, maximum displacement, and the isokinetic muscle function of the trunk in adult females with sedentary work patterns.

2. Materials and Methods

2.1. Design and Participants

A single group crossover design was employed for this study. We included 105 female office workers aged $\geq$ 20 years who did not perform regular exercise for the past 6 months, did not meet the WHO-recommended physical activity levels, and performed at least 7 h of sedentary work per day. We excluded participants with a history of surgery or any musculoskeletal or neurological disorder within the past 3 months. To ensure we included participants without problems performing physical activities, we only selected participants who reported lacking limitations in activities of daily living due to a current health problem or physical or mental disability. This study was approved by the Institutional Review Board of the Incheon National University (INUIRB No. 7007971-202012-003A). The participants provided informed consent after receiving sufficient explanations regarding the study contents and procedures. The specific demographic information and physical activity are shown in Table 1.

Table 1. Demographic information and physical activity of participants.

	Variables	Values
Participants	N	105
	Age (years)	30.99 ± 10.85
	Weight (kg)	57.79 ± 10.44
	Height (cm)	159.99 ± 15.03
Physical Activity	Vigorous intensity (day/week)	0.29 ± 15.03
	Vigorous intensity (min/day)	10.19 ± 19.65
	Moderate intensity (day/week)	0.66 ± 0.90
	Moderate intensity (min/day)	18.35 ± 29.80
	Sedentary time (min/day)	469.71 ± 45.16

Note. Data are mean ± standard deviation.

2.2. Procedures

2.2.1. Tensiomyography

A tensiomyography (TMG-100 System electrostimulator, Slovenia), which is a device used to analyze the contractile properties of muscles, was used to assess the mechanical and neuromuscular properties of the erector spinae (Figure 1). Since Domaszewski et al. [31] reported that caffeine intake may affect muscle contraction time and displacement, the participants were asked to refrain from caffeine intake for 24 h before the measurement. Moreover, the participants were requested to avoid exercise and fascia treatment that could cause fatigue for 48 h before the measurement. Measurements were performed after enough rest to ensure that the erector spinae muscle was maintained in a relaxed state. Further, measurements were performed in a static position to minimize variability of the TMG sensor position. To ensure accurate measurement with minimal lumbar lordosis, a wedge cushion was placed on the ankles and the anterior superior iliac spine (ASIS) in a prone position; moreover, a pad was placed on the ankles to maintain knee flexion at approximately 5°. Subsequently, we examined the proximal region of the erector spinae muscle. The digital displacement sensor (GK40, Ljubljana, Slovenia) was vertically placed 5 cm above the posterior superior iliac spine (PSIS), with a maximum radial displacement (Dm) of 15 mm. The distance between the electrode pads was maintained at 5 cm. A single electrical stimulus was started at 20 mA, followed by 20-mA increments. Measurements were gradually obtained until maximum displacement appeared. A 15 s rest period was allowed between measurements to minimize muscle fatigue; further, all measurements were conducted from right to left.

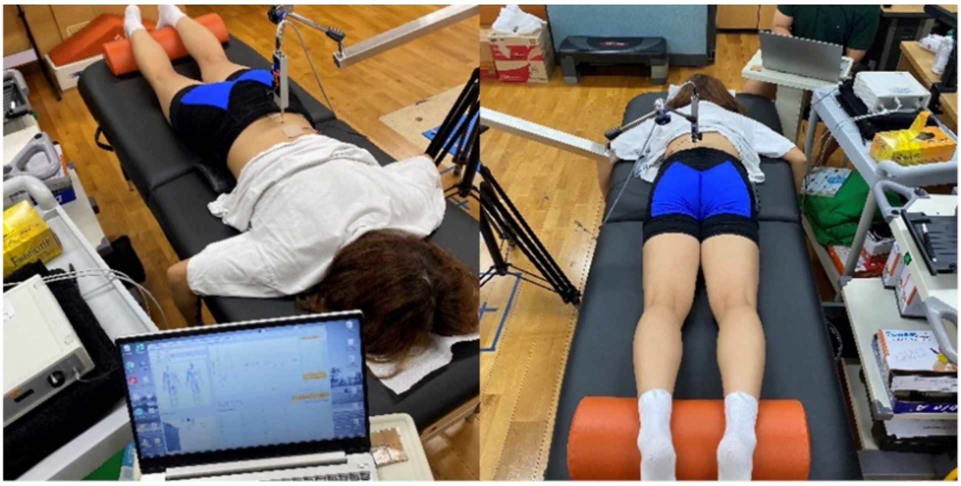

Figure 1. Tensiomyography device and appropriate prone position.

2.2.2. Isokinetic Muscle–Joint Function Test

We performed isokinetic muscle–joint function tests (Humac Norm Testing and Rehabilitation, CSMi Medical & Solution, Stoughton, MA, USA) on the trunk (Figure 2). The participants performed sufficient warm-up exercises, such as dynamic stretching for trunk flexion and extension, before the measurements to prevent injury. A trunk adapter was connected to the dynamometer of the test equipment; additionally, the footpad was adjusted by aligning the anatomical vertical axis with the equipment axis. To generate maximum muscle strength during trunk flexion and extension, the lower extremities were fixed using popliteal, femoral, tibial, and pelvic belts. To minimize interference from nearby joint movements, the upper extremities were fixed using a shoulder pad at the inferior scapular angle. The joint range of motion (ROM) was restricted by setting the ROM to the maximum flexion and extension possible without pain, to prevent injury resulting from excessive flexion or extension. Subsequently, a preliminary exercise was performed to ensure familiarity with the measurement equipment. A 2-min rest period was allowed to minimize muscle fatigue between measurements; further, measurements were performed 5 and 15 times at an angular velocity of 60°/s and 90°/s, respectively.

Figure 2. Humac Norm Testing and Rehabilitation device with trunk adapt.

2.3. Core Stabilization Exercise Program

The exercise program comprised warm-up, main, and cool-down exercises. Warm-up and cool-down exercises were performed for 10 min each using a foam roller to allow self-fascia relaxation as well as static and dynamic stretching, with the intensity set at a pain-free range. The workout mostly comprised core stabilization exercises involving 3 60-min exercise sessions per week. The main exercise focused on muscles around the lower back and hips that contribute to core stabilization, for improved trunk muscle strength and endurance, coordination, proprioceptive function, and stability. Based on previous studies, the core stabilization exercise programs comprised traditional core exercises, including bracing, hollowing to activate the abdominal wall musculature, bird dog, plank, back extensions, and hip bridge, as well as the trunk twist hip bridge to activate the lumbar paraspinals [23,32] (Table 2). Thabet et al. [32] prescribed an exercise intervention to postpartum women that comprised 3 sets of 20 repetitions, with 5 s of contraction and 10 s of relaxation. Since we included healthy adult females, they were requested to perform 5 s of contraction and 5 s of relaxation for more intense exercise.

Table 2. Core stabilization intervention program.

Classification	Exercise Type	Exercise	Intensity	Time
Warm-up	Self-myofascial release (Foam roller)	Quadriceps rolling Hamstring rolling Gluteus rolling Back (lower and upper) rolling	Pain-free range 20 s/1 set Total 3 sets	10 min
	Stretching (Static and Dynamic)	Quadriceps stretching Hamstring stretching Gluteus stretching Erector spinae stretching Cat-camel stretching Hip flexion and extension		
Main Exercise	Core stabilization exercise	Bracing and Hollowing Plank (side and prone) Hip Bridge Back Extension Bird dog Trunk Twist	1 rep (5 s contraction 5 s relaxation) 20 reps/1 set Total 3 sets	40 min
Cool-down	Self-myofascial release (Foam roller)	Quadriceps rolling Hamstring rolling Gluteus rolling Back (lower and upper) rolling	Pain-free range 20 s/1 set Total 3 sets	10 min
	Stretching (Static and Dynamic)	Quadriceps stretching Hamstring stretching Gluteus stretching Erector spinae stretching Cat-camel stretching Hip flexion and extension		

2.4. Data Analysis

2.4.1. Analysis of Mechanical and Neuromuscular Properties of Muscle

To analyze the mechanical and neuromuscular properties, we applied a range of 0.91–0.99 for Dm, which indicates the maximum contractile displacement as the variable with the highest measure-remeasure and intra-rater reliability indices, and a range of 0.70–0.98 for contraction time (Tc), which is the time required for contraction to reach 10–90% of the maximum contractile displacement [33,34]. Since Tc could be influenced by the Dm magnitude, we calculated the mean velocity until 90% Dm (Vc90), using the equation $Vc90 = \frac{Dm*0.9}{Tc+Td}$ to assess muscle contraction velocity [35,36]. Bilateral values of all measured variables were summed, and the mean values were calculated.

2.4.2. Analysis of Isokinetic Muscle Function of Trunk

The maximum muscle strength of the flexor and extensor muscles at all angular velocities was analyzed. The absolute muscle strength was divided by the bodyweight of each participant to derive relative muscle strength. Additionally, to assess the flexor and extensor muscle balance in the trunk, we used the muscle strength ratio to analyze the isokinetic muscle function of the trunk.

2.5. Statistical Processing

All statistical analyses were performed using SPSS 26.0 (IBM, Chicago, IL, USA). The mean and standard deviation of each variable was calculated. The Kolmogorov-Smirnov test showed that the data was not normally distributed. The Wilcoxon signed-rank test was used for within-group comparisons of pre- and post-intervention measurements. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Analysis of Mechanical and Neuromuscular Properties of the Erector Spinae

There was a significant post-exercise change in Dm ($z = -3.998$; $p < 0.001$) and Vc90 ($z = -3.889$; $p < 0.001$), but not Tc ($z = -1.143$; $p = 0.253$) (Table 3).

Table 3. Results of tensiomyography of erector spinae of the participants.

Variables	Pre	Post	*z*	*p*
Tc (ms)	16.37 ± 3.98	16.38 ± 3.44	−1.143	0.253
Dm (mm)	2.49 ± 1.32	2.87 ± 1.14	−3.998	<0.001 ***
Vc90 (mm/ms)	0.06 ± 0.04	0.07 ± 0.03	−3.889	<0.001 ***

Note. Data are mean ± standard deviation, *** $p < 0.001$. Abbreviations: Tc, contraction time; Dm, Maximum radial displacement; Vc90, Mean velocity until 90%.

3.2. Analysis of Isokinetic Muscle Function of Trunk

At an angular velocity of 60°/s, there was a significant post-exercise change in the maximum ($z = -6.605$; $p < 0.001$) and relative muscle strength per bodyweight of the extensor ($z = -6.681$; $p < 0.001$), but there was not a significant post-exercise change for the flexor ($z = -0.686$; $p = 0.493$, $z = -0.887$; $p = 0.375$) (Table 4).

Table 4. Results for isokinetic muscle function of trunk.

Variables			Pre	Post	*z*	*p*
60°/s	Flexor	PT (Nm)	132.19 ± 35.39	135.61 ± 29.74	−0.686	0.493
		PT (%BW)	227.52 ± 49.23	235.01 ± 37.99	−0.887	0.375
	Extensor	PT (Nm)	101.54 ± 37.79	118.92 ± 34.66	−6.605	<0.001 ***
		PT (%BW)	174.21 ± 57.58	206.11 ± 55.59	−6.681	<0.001 ***
	Ratio		139.43 ± 38.16	120.72 ± 31.86	−5.424	<0.001 ***
90°/s	Flexor	PT (Nm)	130.25 ± 34.65	133.55 ± 31.24	−1.461	0.144
		PT (%BW)	224.20 ± 46.92	232.03 ± 41.68	−1.950	0.051
	Extensor	PT (Nm)	88.55 ± 31.71	106.83 ± 30.75	−7.218	<0.001 ***
		PT (%BW)	152.30 ± 48.66	183.65 ± 46.55	−7.232	<0.001 ***
	Ratio		159.21 ± 52.48	132.07 ± 31.52	−6.285	<0.001 ***

Note. Data are mean ± standard deviation, *** $p < 0.001$. Abbreviations: PT, Peak torque; BW, Body weight.

At an angular velocity of 90°/s, there was no significant post-exercise change in the maximum and relative muscle strength ($z = -1.461$; $p = 0.144$, $z = -1.950$; $p = 0.051$) of the flexor muscle (Table 4). However, there was a significant post-exercise change in the maximum and relative muscle strength per bodyweight of the extensor muscle ($z = -7.218$; $p < 0.001$, $z = -7.232$; $p < 0.001$).

Regarding the muscle strength ratio, measurements at an angular velocity of 60°/s ($z = -5.424$; $p < 0.001$) and 90°/s ($z = -6.285$; $p < 0.001$) showed significant differences (Table 4).

4. Discussion and Limitation

This study presented basic data for facilitating the development of an effective exercise intervention program for preventing musculoskeletal disorders caused by a lengthy sedentary lifestyle. We determined the effects of a 7-week core stabilization exercise program on the mechanical and neuromuscular properties of the erector spinae and the isokinetic muscle function of the trunk in adult females who perform $\geq$ 7 h of sedentary work per day.

Regarding the mechanical and neuromuscular properties of the erector spinae muscle, there was a significant post-exercise increase in the Dm and Vc90, but not Tc, values. Tc showed higher and lower values in type I and II muscle fibers, respectively; specifically, Tc has a strong correlation with type I muscle fibers [37,38]. Given the nature of the erector spinae muscle, type I muscle fibers, which have strong fatigue resistance, are more dominant than type IIa or IIx muscle fibers in maintaining lumbar stability through continued contraction [39,40]. Furthermore, it is difficult to convert type I muscle fibers into type IIa and type IIx muscle fibers through training [41]. Consistent with this evidence, we observed no significant post-exercise change in the Tc of the erector spinae muscle.

Consistent with our hypothesis, there was a significant post-exercise increase in Dm. Dm is considered a scale for muscle stiffness; specifically, it is negatively correlated with muscle stiffness [42–44]. A lengthy sedentary lifestyle causes microdamage and spasms in muscle connective tissue, which increases muscle stiffness by restricting muscle tissue microcirculation [45,46]. Moreover, muscle stiffness showed a strong positive correlation with isometric contraction [47]. Kett et al. [8] reported a significant increase in lumbar muscle stiffness after 4–5 h of sedentary work and a significantly reduced muscle stiffness after an 8 min roller massage. Because roller massages break down the cross-bridges between the actin and myosin filaments that were previously formed by the prolonged sitting period, muscle stiffness is significantly reduced. Moreover, the effect of relaxing muscle tension and reducing muscle stiffness owing to self-fascial relaxation using a foam roller is known to have long-term effects [48]. Muscle stiffness increases immediately after exercise, which is relieved with repeated exercise [49]. Accordingly, erector spinae stiffness was reduced in participants through repeated exercise and self-fascial relaxation using a foam roller. As a result, there was a post-exercise increase in Dm.

Consistent with our hypothesis, Vc90 showed a significant post-intervention increase. This suggests a post-exercise increase in the contraction velocity of the erector spinae muscle. Core stabilization exercise can effectively stimulate the sensory receptors and motor control of core muscles and increase neuromuscular control and stability [23], with a concomitant increase in the core muscle activation [21,50]. Specifically, Mannion et al. [51] reported that stabilization exercise for $\geq$3 weeks is required to activate the erector spinae muscle in patients with non-specific chronic low-back pain. Accordingly, there was a post-exercise increase in core muscle activation and neuromuscular control; specifically, TMG measurement revealed an increased contraction velocity through the activation of the erector spinae muscle. This indicated that core stabilization was achieved through enhanced muscle function, which allowed lumbar stabilization during activities of daily living and sports activities, while changing appropriately to maintain proper postural control [40,52].

Regarding the isokinetic muscle function of the trunk, there was no significant post-exercise change in maximum and relative flexor muscle strength at an angular velocity of

60°/s, as well as maximum and relative flexor muscle strength at an angular velocity of 90°/s. However, there was a significant post-exercise increase in other variables, including maximum and relative extensor muscle strength at an angular velocity of 60°/s and 90°/s. Moreover, there was a significant decrease in the muscle ratio (ratio of the flexor and extensor muscles of the trunk) at an angular velocity of 60°/s and 90°/s.

Our findings demonstrated that the core stabilization exercise program strengthens core muscles, which improves the balanced development of flexor and extensor muscles, as well as enhances the isokinetic muscle functions of the trunk, including muscle strength and endurance. Accordingly, core stabilization exercises could effectively increase muscle strength in the trunk and improve neuromuscular imbalance. Moreover, a 12-week core stabilization exercise program was found to improve the strength of the lumbar flexor and extensor muscles in primary school students with scoliosis [53]. Additionally, an 8-week core stabilization exercise program was found to significantly increase flexor and extensor muscle strength at an angular velocity of 60°/s and 90°/s in women with a sedentary lifestyle [54]. Furthermore, Sipaviciene et al. [30] reported a 12-week lumbar stabilization exercise program improved isokinetic muscle function of the trunk in patients with non-specific chronic low-back pain. As aforementioned, most studies have demonstrated that core stabilization exercise enhances core muscle strength. In addition, core stabilization exercise increases lumbar stability by strengthening the core flexor and extensor muscles, as well as the contractile and neuromuscular control functions [55]. Consistent with these previous findings, we observed a significant post-exercise decrease in the muscle strength ratio, which was effective for the balanced development of core muscles.

The core muscles represent the anatomical and functional center of the body and play a corset-like role in stabilizing the body and spine [56]. Weakened lumbar muscles cause deterioration of the spinal stabilization function, which can be a primary cause of low-back pain [12,13]. Conversely, strengthening core muscles enhances core stability and is crucially involved in performing activities of daily living or various other activities, as well as maintaining posture and balance [57,58]. Our core stabilization exercise program enhanced lumbar muscle function and strength, which can enhance core stability and prevent musculoskeletal disorders caused by a lengthy sedentary lifestyle.

This study suggests that the core stabilization exercise program may have a positive effect on muscle stiffness and contraction rates in the group with long-term sedentary lifestyles. In addition, tensiomyography can be used to clinically evaluate muscle contraction characteristics. Limitations of this study were that there was no control group and only healthy subjects were recruited. In future studies, it is necessary to further study the effect of the core stabilization exercise program by composing a control group and a low-back-pain group.

5. Conclusions

This study presented basic data for facilitating the development of an exercise program for preventing musculoskeletal disorders caused by a sedentary lifestyle, by analyzing the effects of core stabilization exercise on the muscle contraction properties of the erector spinae and changes in the isokinetic muscle function in adult females with a sedentary lifestyle. We found that the 7-week core stabilization exercise program could effectively reduce muscle stiffness in the erector spinae muscle; moreover, it increased contraction velocity through activation of the neuromuscular control of the erector spinae muscle, and effectively enhanced isokinetic muscle function of the trunk.

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References

1. Owen, N.; Healy, G.N.; Matthews, C.E.; Dunstan, D.W. Too Much Sitting: The Population-Health Science of Sedentary Behavior. *Exerc. Sport Sci. Rev.* **2010**, *38*, 105–113. [CrossRef] [PubMed]
2. Romero-Blanco, C.; Rodríguez-Almagro, J.; Onieva-Zafra, M.D.; Parra-Fernández, M.L.; Prado-Laguna, M.D.C.; Hernández-Martínez, A. Physical Activity and Sedentary Lifestyle in University Students: Changes during Confinement Due to the COVID-19 Pandemic. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6567. [CrossRef] [PubMed]
3. Stockwell, S.; Trott, M.; Tully, M.; Shin, J.; Barnett, Y.; Butler, L.; McDermott, D.; Schuch, F.; Smith, L. Changes in physical activity and sedentary behaviours from before to during the COVID-19 pandemic lockdown: A systematic review. *BMJ Open Sport Exerc. Med.* **2021**, *7*, e000960. [CrossRef]
4. Pratt, M.; Varela, A.R.; Salvo, D.; Kohl, H.W., III; Ding, D. Attacking the pandemic of physical inactivity: What is holding us back? *Br. J. Sports Med.* **2020**, *54*, 760–762. [CrossRef] [PubMed]
5. Ozemek, C.; Lavie, C.J.; Rognmo, Ø. Global physical activity levels-Need for intervention. *Prog. Cardiovasc. Dis.* **2019**, *62*, 102–107. [CrossRef]
6. Heneweer, H.; Vanhees, L.; Picavet, H.S.J. Physical activity and low back pain: A U-shaped relation? *Pain* **2009**, *143*, 21–25. [CrossRef]
7. Moreno, M.A.; Catai, A.M.; Teodori, R.M.; Borges, B.L.A.; Cesar, M.d.C.; Silva, E.d. Effect of a muscle stretching program using the Global Postural Reeducation method on respiratory muscle strength and thoracoabdominal mobility of sedentary young males. *J. Bras. Pneumol.* **2007**, *33*, 679–686. [CrossRef]
8. Kett, A.R.; Sichting, F. Sedentary behaviour at work increases muscle stiffness of the back: Why roller massage has potential as an active break intervention. *Appl. Ergon.* **2020**, *82*, 102947. [CrossRef]
9. Cho, K.H.; Beom, J.W.; Lee, T.S.; Lim, J.H.; Lee, T.H.; Yuk, J.H. Trunk Muscles Strength as a Risk Factor for Nonspecific Low Back Pain: A Pilot Study. *Ann. Rehabil. Med.* **2014**, *38*, 234–240. [CrossRef]
10. Saiklang, P.; Puntumetakul, R.; Selfe, J.; Yeowell, G. An Evaluation of an Innovative Exercise to Relieve Chronic Low Back Pain in Sedentary Workers. *Hum. Factors* **2020**, 1–15. [CrossRef]
11. Kett, A.R.; Sichting, F.; Milani, T.L. The Effect of Sitting Posture and Postural Activity on Low Back Muscle Stiffness. *Biomechanics* **2021**, *1*, 214–224. [CrossRef]
12. Kuster, R.P.; Bauer, C.M.; Baumgartner, D. Is active sitting on a dynamic office chair controlled by the trunk muscles? *PLoS ONE* **2020**, *15*, e0242854. [CrossRef] [PubMed]
13. Mörl, F.; Bradl, I. Lumbar posture and muscular activity while sitting during office work. *J. Electromyogr. Kinesiol.* **2013**, *23*, 362–368. [CrossRef] [PubMed]
14. Park, J.H.; Seo, K.S.; Lee, S.U. Effect of Superimposed Electromyostimulation on Back Extensor Strengthening: A Pilot Study. *J. Strength Cond. Res.* **2016**, *30*, 2470–2475. [CrossRef]
15. Hanna, F.; Daas, R.N.; El-Shareif, T.J.; Al-Marridi, H.H.; Al-Rojoub, Z.M.; Adegboye, O.A. The Relationship Between Sedentary Behavior, Back Pain, and Psychosocial Correlates Among University Employees. *Front. Public Health* **2019**, *7*, 80. [CrossRef]
16. Nowotny, A.H.; Calderon, M.G.; de Souza, P.A.; Aguiar, A.F.; Léonard, G.; Alves, B.M.O.; Amorim, C.F.; da Silva, R.A. Lumbar stabilisation exercises versus back endurance-resistance exercise training in athletes with chronic low back pain: Protocol of a randomised controlled trial. *BMJ Open Sport Exerc. Med.* **2018**, *4*, e000452. [CrossRef]
17. Bento, T.P.F.; dos Santos Genebra, C.V.; Maciel, N.M.; Cornelio, G.P.; Simeão, S.F.A.P.; de Vitta, A. Low back pain and some associated factors: Is there any difference between genders? *Braz. J. Phys. Ther.* **2020**, *24*, 79–87. [CrossRef]
18. Wu, A.; March, L.; Zheng, X.; Huang, J.; Wang, X.; Zhao, J.; Blyth, F.M.; Smith, E.; Buchbinder, R.; Hoy, D. Global low back pain prevalence and years lived with disability from 1990 to 2017: Estimates from the Global Burden of Disease Study 2017. *Ann. Transl. Med.* **2020**, *8*, 299. [CrossRef]

19. Palacios-Ceña, D.; Albaladejo-Vicente, R.; Hernández-Barrera, V.; Lima-Florencio, L.; Fernández-de-Las-Peñas, C.; Jimenez-Garcia, R.; López-de-Andrés, A.; de Miguel-Diez, J.; Perez-Farinos, N. Female gender is associated with a higher prevalence of chronic neck pain, chronic low back pain, and migraine: Results of the Spanish National Health Survey, 2017. *Pain. Med.* **2021**, *22*, 382–395. [CrossRef]
20. Patil, S.; Mahajan, A. Effect of Graded Plank Protocol on Core Stability in Sedentary Dentists. *Int. J. Res. Rev.* **2020**, *7*, 407–411.
21. Narouei, S.; hossein Barati, A.; Akuzawa, H.; Talebian, S.; Ghiasi, F.; Akbari, A.; hossein Alizadeh, M. Effects of core stabilization exercises on thickness and activity of trunk and hip muscles in subjects with nonspecific chronic low back pain. *J. Bodyw. Mov. Ther.* **2020**, *24*, 138–146. [CrossRef] [PubMed]
22. Kim, S.G.; Yong, M.S.; Na, S.S. The Effect of Trunk Stabilization Exercises with a Swiss Ball on Core Muscle Activation in the Elderly. *J. Phys. Ther. Sci.* **2014**, *26*, 1473–1474. [CrossRef]
23. Akuthota, V.; Ferreiro, A.; Moore, T.; Fredericson, M. Core Stability Exercise Principles. *Curr. Sports Med. Rep.* **2008**, *7*, 39–44. [CrossRef] [PubMed]
24. Miguel, A.; Pardos-Sevilla, A.I.; Jiménez-Fuente, A.; Hubler-Figueiró, T.; d'Orsi, E.; Rech, C.R. Associations of Mutually Exclusive Categories of Physical Activity and Sedentary Time With Metabolic Syndrome in Older Adults: An Isotemporal substitution approach. *J. Aging Phys. Act.* **2021**, *1*, 1–9. [CrossRef]
25. Hopstock, L.A.; Deraas, T.S.; Henriksen, A.; Martiny-Huenger, T.; Grimsgaard, S. Changes in adiposity, physical activity, cardiometabolic risk factors, diet, physical capacity and well-being in inactive women and men aged 57–74 years with obesity and cardiovascular risk–A 6-month complex lifestyle intervention with 6-month follow-up. *PLoS ONE* **2021**, *16*, e0256631. [CrossRef] [PubMed]
26. Lind, L.; Zethelius, B.; Lindberg, E.; Pedersen, N.L.; Byberg, L. Changes in leisure-time physical activity during the adult life span and relations to cardiovascular risk factors—Results from multiple Swedish studies. *PLoS ONE* **2021**, *16*, e0256476. [CrossRef] [PubMed]
27. Park, S.; Nam, J.Y. The Impact of Sedentary Behavior and Self-Rated Health on Cardiovascular Disease and Cancer among South Korean Elderly Persons Using the Korea National Health and Nutrition Examination Survey (KNHANES) 2014–2018 Data. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7426. [CrossRef]
28. García-Unanue, J.; Felipe, J.L.; Bishop, D.; Colino, E.; Ubago-Guisado, E.; López-Fernández, J.; Hernando, E.; Gallardo, L.; Sánchez-Sánchez, J. Muscular and Physical Response to an Agility and Repeated Sprint Tests According to the Level of Competition in Futsal Players. *Front. Psychol.* **2020**, *11*, 3671. [CrossRef]
29. Kim, S.; Jee, Y. Effects of 3D Moving Platform Exercise on Physiological Parameters and Pain in Patients with Chronic Low Back Pain. *Medicina* **2020**, *56*, 351. [CrossRef]
30. Sipaviciene, S.; Kliziene, I.; Pozeriene, J.; Zaicenkoviene, K. Effects of a Twelve-Week Program of Lumbar-Stabilization Exercises on Multifidus Muscles, Isokinetic Peak Torque and Pain for Women with Chronic Low Back Pain. *J. Pain Relief.* **2018**, *7*, 1–10. [CrossRef]
31. Domaszewski, P.; Pakosz, P.; Konieczny, M.; Bączkowicz, D.; Sadowska-Krępa, E. Caffeine-Induced Effects on Human Skeletal Muscle Contraction Time and Maximal Displacement Measured by Tensiomyography. *Nutrients* **2021**, *13*, 815. [CrossRef] [PubMed]
32. Thabet, A.A.; Alshehri, M.A. Efficacy of deep core stability exercise program in postpartum women with diastasis recti abdominis: A randomised controlled trial. *J. Musculoskelet Neuronal. Interact.* **2019**, *19*, 62–68. [PubMed]
33. Križaj, D.; Šimunič, B.; Žagar, T. Short-term repeatability of parameters extracted from radial displacement of muscle belly. *J. Electromyogr. Kinesiol.* **2008**, *18*, 645–651. [CrossRef] [PubMed]
34. Martín-Rodríguez, S.; Loturco, I.; Hunter, A.M.; Rodríguez-Ruiz, D.; Munguia-Izquierdo, D. Reliability and measurement error of tensiomyography to assess mechanical muscle function: A systematic review. *J. Strength Cond. Res.* **2017**, *31*, 3524–3536. [CrossRef] [PubMed]
35. Loturco, I.; Pereira, L.A.; Kobal, R.; Kitamura, K.; Ramírez-Campillo, R.; Zanetti, V.; Abad, C.C.C.; Nakamura, F.Y. Muscle Contraction Velocity: A Suitable Approach to Analyze the Functional Adaptations in Elite Soccer Players. *J. Sports Sci. Med.* **2016**, *15*, 483–491.
36. Lohr, C.; Braumann, K.-M.; Reer, R.; Schroeder, J.; Schmidt, T. Reliability of tensiomyography and myotonometry in detecting mechanical and contractile characteristics of the lumbar erector spinae in healthy volunteers. *Eur. J. Appl. Physiol.* **2018**, *118*, 1349–1359. [CrossRef]
37. Dahmane, R.; Valenčič, V.; Knez, N.; Eržen, I. Evaluation of the ability to make non-invasive estimation of muscle contractile properties on the basis of the muscle belly response. *Med. Biol. Eng. Comput.* **2001**, *39*, 51–55. [CrossRef]
38. Valenčič, V.; Knez, N. Measuring of Skeletal Muscles' Dynamic Properties. *Artif. Organs* **1997**, *21*, 240–242. [CrossRef]
39. Agten, A.; Stevens, S.; Verbrugghe, J.; Eijnde, B.O.; Timmermans, A.; Vandenabeele, F. The lumbar multifidus is characterised by larger type I muscle fibres compared to the erector spinae. *Anat. Cell Biol.* **2020**, *53*, 143–150. [CrossRef]
40. Mannion, A.F.; Dumas, G.A.; Cooper, R.G.; Espinosa, F.; Faris, M.W.; Stevenson, J.M. Muscle fibre size and type distribution in thoracic and lumbar regions of erector spinae in healthy subjects without low back pain: Normal values and sex differences. *J. Anat.* **1997**, *190*, 505–513. [CrossRef]
41. Karp, J.R. Muscle Fiber Types and Training. *Strength Cond. J.* **2001**, *23*, 21–26. [CrossRef]

42. de Paula Simola, R.Á.; Harms, N.; Raeder, C.; Kellmann, M.; Meyer, T.; Pfeiffer, M.; Ferrauti, A. Assessment of Neuromuscular Function After Different Strength Training Protocols Using Tensiomyography. *J. Strength Cond. Res.* **2015**, *29*, 1339–1348. [CrossRef] [PubMed]
43. García-Manso, J.M.; Rodríguez-Matoso, D.; Sarmiento, S.; de Saa, Y.; Vaamonde, D.; Rodríguez-Ruiz, D.; Da Silva-Grigoletto, M.E. Effect of high-load and high-volume resistance exercise on the tensiomyographic twitch response of biceps brachii. *J. Electromyogr. Kinesiol.* **2012**, *22*, 612–619. [CrossRef] [PubMed]
44. García-Manso, J.M.; Rodríguez-Ruiz, D.; Rodríguez-Matoso, D.; de Saa, Y.; Sarmiento, S.; Quiroga, M. Assessment of muscle fatigue after an ultra-endurance triathlon using tensiomyography (TMG). *J. Sports Sci.* **2011**, *29*, 619–625. [CrossRef] [PubMed]
45. Proske, U.; Morgan, D.L. Do cross-bridges contribute to the tension during stretch of passive muscle? *J. Muscle Res. Cell Motil.* **1999**, *20*, 433–442. [CrossRef]
46. Solomonow, M. Neuromuscular manifestations of viscoelastic tissue degradation following high and low risk repetitive lumbar flexion. *J. Electromyogr. Kinesiol.* **2012**, *22*, 155–175. [CrossRef]
47. Wilke, J.; Vogt, L.; Pfarr, T.; Banzer, W. Reliability and validity of a semi-electronic tissue compliance meter to assess muscle stiffness. *J. Back. Musculoskelet Rehabil.* **2018**, *31*, 991–997. [CrossRef]
48. Kenny, G.P.; Reardon, F.D.; Zaleski, W.; Reardon, M.L.; Haman, F.; Ducharme, M.B. Muscle temperature transients before, during, and after exercise measured using an intramuscular multisensor probe. *J. Appl. Physiol.* **2003**, *94*, 2350–2357. [CrossRef]
49. Janecki, D.; Jarocka, E.; Jaskólska, A.; Marusiak, J.; Jaskólski, A. Muscle passive stiffness increases less after the second bout of eccentric exercise compared to the first bout. *J. Sci. Med. Sport* **2011**, *14*, 338–343. [CrossRef]
50. Areeudomwong, P.; Puntumetakul, R.; Jirarattanaphochai, K.; Wanpen, S.; Kanpittaya, J.; Chatchawan, U.; Yamauchi, J. Core Stabilization Exercise Improves Pain Intensity, Functional Disability and Trunk Muscle Activity of Patients with Clinical Lumbar Instability: A Pilot Randomized Controlled Study. *J. Phys. Ther. Sci.* **2012**, *24*, 1007–1012. [CrossRef]
51. Mannion, A.F.; Taimela, S.; Müntener, M.; Dvorak, J. Active Therapy for Chronic Low Back Pain: Part 1. Effects on Back Muscle Activation, Fatigability, and Strength. *Spine* **2001**, *26*, 897–908. [CrossRef] [PubMed]
52. Calatayud, J.; Casaña, J.; Martín, F.; Jakobsen, M.D.; Colado, J.C.; Andersen, L.L. Progression of Core Stability Exercises Based on the Extent of Muscle Activity. *Am. J. Phys. Med. Rehabil.* **2017**, *96*, 694–699. [CrossRef] [PubMed]
53. Ko, K.J.; Kang, S.J. Effects of 12-week core stabilization exercise on the Cobb angle and lumbar muscle strength of adolescents with idiopathic scoliosis. *J. Exerc. Rehabil.* **2017**, *13*, 244–249. [CrossRef] [PubMed]
54. Sekendiz, B.; Cug, M.; Korkusuz, F. Effects of Swiss-ball Core Strength Training on Strength, Endurance, Flexibility, and Balance in Sedentary Women. *J. Strength Cond. Res.* **2010**, *24*, 3032–3040. [CrossRef]
55. Barr, K.P.; Griggs, M.; Cadby, T. Lumbar Stabilization Core Concepts And Current Literature, Part 1. *Am. J. Phys. Med. Rehabil.* **2005**, *84*, 473–480. [CrossRef]
56. Miyake, Y.; Kobayashi, R.; Kelepecz, D.; Nakajima, M. Core exercises elevate trunk stability to facilitate skilled motor behavior of the upper extremities. *J. Bodyw. Mov. Ther.* **2013**, *17*, 259–265. [CrossRef]
57. Granacher, U.; Gollhofer, A.; Hortobágyi, T.; Kressig, R.W.; Muehlbauer, T. The Importance of Trunk Muscle Strength for Balance, Functional Performance, and Fall Prevention in Seniors: A Systematic Review. *Sports Med.* **2013**, *43*, 627–641. [CrossRef]
58. Maeo, S.; Takahashi, T.; Takai, Y.; Kanehisa, H. Trunk Muscle Activities During Abdominal Bracing: Comparison Among Muscles And Exercises. *J. Sports Sci. Med.* **2013**, *12*, 467–474.