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THE EFFECT OF 12 WEEKS CORE EXERCISE ON MECHANICAL PROPERTIES OF LOWER EXTREMITY MUSCLES WITH HEALTHY YOUNG INDIVIDUALS

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ABSTRACT

Core exercise (CE) is widely used in sports medicine and rehabilitation programs. Most examinations have mostly concentrated on the axial skeleton, while overlooking the upper and lower extremity. The core motion principle is designed to transfer force and momentum from the core area to the extremity using the kinetic chain hypothesis. Thus, it is essential to examine the beneficial impacts of CE on the lower extremity. We used MyotonPRO to study how different CEs affect muscle tone in healthy persons. Twenty-three healthy individuals (12 males, 11 females; mean age M/F=21.4±1.0/21.0±1.6 years) participated in a 12-week program, exercising a minimum of three times per week for 80 minutes per session. Twelve individuals were members of the CE Group (CEG) and followed the CE throughout, whereas 11 people belonged to the Non-CE Group (NCEG) and stopped the program after a week. The CE regimen included five primary exercises: squat, skater, plank, crunch & bridge, and leg raise. muscle tone was evaluated with MyotonPRO by measuring oscillation frequency (F, Hz), which reflects the inherent muscle tone during a state of rest with involuntary contraction. Participants were assessed using MyotonPRO for rectus femoris (RF) and tibialis anterior (TA) in a supine posture and for biceps femoris (BF) and gastrocnemius (GCM) in a prone position on their dominant lower extremity. There were no notable variations between the pre and post-test in the NCEG. However, the F values of all muscles in the CEG significantly rose, with the largest significant change noted in the calf region. The 12-week core workout program is thought to have had a beneficial impact on muscle tone. Implementing certain time and intensity of core workouts can assist regulate muscle tone and reduce the risk of lower extremity injuries during different exercises.

Keywords; Muscle tone; Mechanical properties; MyotonPRO; Core exercise, Gastrocnemius; hamstring; Rectus femoris; Tibialis anterior

1. INTRODUCTION

National advisory groups, public health agencies, and healthcare systems worldwide prioritize physical activities that are favorable to health[1, 2]. Fitness programs like Pilates, yoga, and Tai Chi are based on Core exercise (CE) principles and include a range of physical exercises known for their health advantages[3].

CE is a fundamental component of these regimens, utilized in various contexts such as fitness for healthy individuals, rehabilitation for patients, and training for athletes. Structured core workouts, involving various activities to develop core stability and muscle strength, are crucial for preventing injuries and boosting general mobility. The workouts target stabilizing the central core area to support functional movements in the distant extremity, encompassing both the upper and lower extremity[4].

CE is gaining recognition in sports medicine[5, 6] and rehabilitation programs for issues including [7-9] and neck discomfort[10] due to its established favorable effects on muscle architecture and intrinsic features.

Although CEs are commonly performed, studies on their effectiveness, as outlined by Behm (2010), have mostly concentrated on the central part of the body, such as the shoulder and pelvic girdles, and core muscles such the lumbar multifidus, transverse abdominis, and quadratus lumborum. These examinations frequently neglected the upper and lower extremity[11, 12].

Statistical data from the United States[13] and Europe[14] emphasize the common occurrence of joint sprains and muscle strains in sports and leisure activities. This has led to further study on CEs as a way to reduce lower extremity injuries[15].

The kinetic chain theory is fundamental to the CE principle, highlighting the transfer of force and momentum from the core to the extremity[11, 16]. This emphasizes the need for more research on the impact of CE on the lower extremity, an area that has not been thoroughly investigated.

Historically, there have been several approaches to assessing muscle characteristics in the lower extremity, but current studies have focused on using isokinetic activities and electromyography (EMG) to quantify muscle activity. The MyotonPRO provides a non-invasive and validated method to evaluate muscle characteristics. It is being used more frequently in clinical and sports research to measure different muscle conditions such as elasticity, force, and stiffness based on physiological and mechanical properties[17-21].

In a resting state without voluntary contraction, the MyotonPRO can accurately measure mechanical properties such as muscle tone (F, Hz), elasticity (D), and stiffness (S, N/m) of the musculoskeletal system, providing a detailed assessment of muscle characteristics[18].

This study intends to assess alterations in lower extremity muscle tone following 12 weeks of core training techniques, with a specific focus on the muscles of the dominant side. This study explores how CE affects muscle properties, which could have consequences for injury prevention and training programs in the future.

2. MATERIAL AND METHODS

2-1. Participants

The study 23 healthy individuals (n=23) who participated in the research. The 12-week CE program was conducted with volunteers who provided informed consent after understanding the experimental procedures, as per the pre-approved RERI-IRB-210416. (Table 1).

All participants in the study were healthy individuals with no history of musculoskeletal injury to the lower extremity within the past 3 years. They were selected based on the criterion that they had not engaged in a CE program or similar activities for the preceding 6 months. Although all subjects initially participated in the CE program, 12 of them continued to adhere to the program perfectly for 12 weeks in the Core exercise group (CEG, n=12), while the remaining 11 subjects did not adhere to the CE program and discontinued participation before one week in the Non- core exercise group (NCEG, n=11). Additionally, all subjects were assessed to determine their dominant lower extremity, which was determined by the extremity they preferentially used to kick a ball[23].

All subjects underwent two measurements of muscle properties using MyotonPRO at the beginning of the program (pre-test) and after 12 weeks (post-test). The NCEG did not participate in any other types of exercise programs during the 12-week period. Information on all subjects is presented in Table 1.

Table 1: General characteristics of subjects

	Total(n=23)			CEG(n=12)			NCEG(n=11)		
Gender	M/F=12/11			M/F=6/6			M/F=6/5		
Dominant side	Rt/Lt=23/0			Rt/Lt=12/0			Rt/Lt=11/0		
	Mean (SD)	Min-Max		Mean (SD)	Min-Max		Mean (SD)	Min-Max	*p*-value

Age, yr	Fe.	21.4 (1.0)	20-24		21.8 (1.3)	21-24		20.8 (1.1)	20-22	0.247
	Ma.	21.0 (1.6)	19-24		21.7 (2.3)	19-24		20.3 (1.0)	19-22	0.394
Height, cm	Fe.	164.6 (4.3)	154-187		164.3 (11.9)	154-187		164.8 (1.3)	163-166	0.429
	Ma.	178.0 (8.4)	168-190		181.7 (8.9)	170-190		174.3 (6.2)	168-185	0.240
Weight, kg	Fe.	60.3 (5.9)	51.9-92.3		60.0 (15.9)	51.9-92.3		60.7 (6.7)	53.6-69.1	0.329
	Ma.	72.3 (12.9)	59.5-99.9		78.7 (15.2)	59.5-99.9		65.9 (2.6)	63.0-70.6	0.093
BMI, g/m^2	Fe.	22.1 (2.1)	19.5-26.4		21.9 (2.3)	20.0-26.4		22.4 (2.8)	19.5-26.0	1.000
	Ma.	22.9 (2.5)	20.3-27.7		24.1 (2.8)	20.3-27.7		21.7 (0.9)	20.5-23.1	0.132

CEG: Core exercise group, NCEG: Non_core exercise group, Gender Ma./Fe.: Male/Female, Dominant side Rt/Lt: right/left, *p*-value: between CEG and NCEG value. All data values were confirmed as homogeneity between groups ($p > 0.05$).

2-2. Procedure of Core Exercise

The 12-week CE program was designed for healthy subjects with consideration given to their physical abilities to study the intrinsic characteristics of the lower extremity muscles. We conducted a total of two measurements: a pre-test before the start of the program and a post-test after applying the 12-week CE program. The program was implemented at least three times per week, with each session lasting 80 minutes. The total program time of 80 minutes comprised a 10-minute warm-up, 60 minutes of the main program, and a 10-minute cool-down. The exercise intensity was moderate to slightly difficult, considering the clinical condition of the subjects.

To prevent boredom and enhance effectiveness through varied CEs, the program consisted of five major CEs (squat, skater, plank, crunch & bridge, and leg raise), which were equally applied to all subjects during the 60-minute main program.

First, the squat exercise strengthens bone density, ligaments, and tendons while also training the thigh, trunk, and buttock muscles. Historically utilized for enhancing the physical abilities and movements of athletes, squat exercises are now commonly employed by individuals seeking to improve health or strengthen their lower extremity[24].

Second, the skater exercise was included, incorporating Proprioceptive Neuromuscular Facilitation (PNF) and core training. Known for its effectiveness in enhancing flexibility, the skater exercise is utilized to prevent injuries that may arise during both daily activities and athletic endeavors[5, 25, 26].

Third, the plank exercise originated as a diagnostic tool for assessing core muscle issues, and it has evolved into a popular exercise for strengthening core muscles, including those in the lumbar, pelvis, and hips[24, 27, 28].

Fourth, crunch & bridge exercises are known to have a positive effect on daily life extremity movement, enhancing balance ability against gravity and postural control by activating trunk muscles[29-31].

Fifth, the leg raise involves fixing the upper body in a supine position and lifting the lower extremity with straight knees. This exercise induces isotonic contraction of the leg-lifting muscles and has the effect of developing the lower abdominal muscles[32].

2-3. Measurement Procedure using MyotonPRO on Muscles of Lower Extremity

Each participant was instructed to lay comfortably in the supine position on the measuring table for approximately 10 minutes to allow for the soft tissue to stabilize. During this time, measurements were taken for the rectus femoris (RF) and tibialis anterior (TA) muscles, with the subjects remaining in the supine position. For measurements of the biceps femoris (BF) and gastrocnemius (GCM) muscles of the dominant lower extremity, participants were positioned prone. The measurement sites were marked with the knee and hip comfortably extended[34-36].

A professional examiner followed the guidelines outlined in the MyotonPRO user manual to locate the muscle belly, origin, and insertion of each muscle. Subsequently, the examiner marked the measurement site in the middle of each muscle using a permanent pen [22]. The indoor temperature of the laboratory was maintained between 22-24°C, with optimal humidity set at 40-60%[33]. To prevent skin changes due to temperature variations, participants wore warm clothing during the measurements[33].

Muscle tone was evaluated through oscillation frequency (F, Hz) by using MyotonPRO which was measured three times and then the average value was applied. If the coefficient of variation was more than 3%, the measurement was repeated. Mechanical stimulation was applied to each muscle belly with 0.18 N (pre-load) and 0.40 N [37, 38]. The reliability of MyotonPRO has been confirmed in previous studies [19-21, 39-41]. Oscillation frequency indicates the intrinsic tension of the muscle in the resting state with nonvoluntary contraction, known as muscle tone.

2-4. Statistical Analysis

The general information of all participants was presented as means with standard deviations (SD). The MyotonPRO results were analyzed for F concerning the RF, TA, BF, and GCM of the dominant side of the lower extremity.

Firstly, a normality test was conducted for all results of the two groups. Statistical analyses included the Mann-Whitney U test and independent two-sample t-test, considering parametric or nonparametric tests for comparison between the two groups. Additionally, Wilcoxon's signed-rank test and Paired Samples t Test were used to assess changes between pre and post results within each group.

A 2-way repeated measures ANOVA was conducted to examine the interaction between time and group. The statistical significance level for all results was set to 0.05. Data from the MyotonPRO experiments were expressed as the mean, standard deviation, and %Difference (post-pre/pre-result*100, %Diff). SPSS 18.0 Windows Ver. (IBM, USA) and Microsoft Office Excel Ver. 2013 standard (Microsoft, USA) were utilized.pon analyzing previous studies, they performed preprocessing techniques to transform discrete or continuous data, but they did not apply the transformed data interchangeably to regression or classification algorithms. Therefore, a preprocessing method is needed to transform the data, like discrete data to a regression algorithm or continuous data to a classification algorithm. Additionally, a method is needed to enable the learning of such preprocessed data regardless of the type of regression or classification algorithm.

3. RESULT

At baseline, there were no significant differences observed between the exercise and non-exercise groups in terms of the variables that are Rt_RF_F, Rt_BF_F, Rt_GCM_F, and Rt_TA_F, and the pre-test was conducted under identical conditions(Rt_RF_F: p=0.907, Rt_BF_F: p=0.719, Rt_GCM_F: p=0.544, Rt_TA_F: p=0.576) in Table 2.

Table 2: Results of frequency through statistical analysis methods

	Group	Independent two sample *t*-test & Paired Samples *t* Test				2-way RM ANOVA		
		Pre	Post	*%Di.*	*p_Time*	So.	*F*	*p*
Rt_RF_F	CEG(n=12)	15.05±1.6†	16.12±1.84	7.09	0.003	T	11.512	0.003
	NCEG(n=11)	15.12±1.13	15.63±1.23	3.37	0.144	G	0.133	0.719
	p_Group	0.907	0.460			T*G	1.441	0.243
Rt_BF_F	CEG(n=12)	15.08±1.42	16.01±1.18	6.13	0.005	T	11.179	0.003
	NCEG(n=11)	15.37±2.24	15.88±1.68	3.31	0.115	G	0.015	0.903
	p_Group	0.719	0.839			T*G	0.94	0.343
Rt_GCM_F	CEG(n=12)	16.01±1.40	17.42±1.31	8.80	0.002	T	12.116	0.002
	NCEG(n=11)	16.42±1.75	17.01±1.90	3.60	0.169	G	0	0.999
	p_Group	0.544	0.560			T*G	2.026	0.169
Rt_TA_F	CEG(n=12)	20.88±2.11	23.51±2.03	12.57	0.002	T	11.669	0.003
	NCEG(n=11)	21.40±2.24	22.37±2.20	4.55	0.215	G	0.183	0.673
	p_Group	0.576	0.213			T*G	2.461	0.132

†Mean±standard deviation, CEG: core exercise group, NCEG: non_core exercise group, Rt: right, RF: rectus femoris, BF: biceps femoris, GCM: gastrocnemius region, TA: tibialis anterior, F: Oscillation frequency (=muscle tone, Hz), %Di.: difference (Post-Pre)/Pre*100, *p*_Time: *p* value between Pre and Post session, *p*_Group: *p* value between CEG and NCEG, T*G: Time*Group, So.: Source

Over the course of 12 weeks, no significant changes were observed in the F variable of all lower extremity muscles in the NCEG. However, in the CEG where five CEs were systematically implemented, all post-results of Rt_RF_F, Rt_BF_F, Rt_GCM_F, and Rt_TA_F significantly increased compared to the pre-result (all $p<0.003$). The post-result (23.51±2.03 Hz) of Rt_TA_F showing the highest rate of change increased significantly by 12.57% compared to the pre-result (20.88±2.11 Hz) in the CEG($p=0.002$).

In the CEG showing the second-highest change among the four lower extremity muscles, the post-intervention and pre-results for Rt_GCM_F were 17.42±1.31 and 16.01±1.4, respectively, indicating a significant 8.8% increase post-intervention compared to baseline($p=0.002$).

The post-intervention increases rates compared to baseline for Rt_RF_F and Rt_BF_F above knee region 7.09% and 6.13%, respectively, showing a significant increase (Rt_RF_F: $p=0.003$, Rt_BF_F: 0.005). The Time*Group interaction for all variables did not show significant results. However, significant differences over time were observed in the CEG for Rt_RF_F, Rt_BF_F, Rt_GCM_F, and Rt_TA_F.

4. DISCUSSION

This study examined the mechanical characteristics of the dominant-side RF, BF, GM, and TA in healthy adults after a 12-week core training program. Muscle tone indicates the baseline tension in muscles. It significantly increased in all lower extremity muscles in the CEG over 12 weeks, while no significant changes were seen in any muscles in the NCEG.

Our results differ from Uysal et al.'s (2021) study, which reported no notable variations in hamstring_F and quadriceps_F after an 8-week Nordic hamstring workout program in healthy adult males (n=40, age=22.3±1.6 years) [42] . The difference may be due to the fact that isotonic-focused Nordic hamstring exercises mainly focus on eccentric strength and fascicle lengthening of the hamstrings, which may not significantly affect the rise in muscle tone[43].

Muscle tone is linked to sustaining muscular tension through central, peripheral nervous system, and joint mechanical qualities, which help in maintaining bodily balance and stability[18]. Thus, it is recommended that static CEs be used to enhance muscle tone by preserving body balance and stability, as they may offer more benefits than active Nordic activities.

The TA_F value of 23 participants was comparatively greater than the F values of other muscle groups in our study. These findings are consistent with Engin et al.'s (2020) study, which determined standard values and observed notably higher TA_F values in the 18-28 age bracket in comparison to older age brackets[44]. The post-intervention frequency of 23.51±2.0 Hz was greater than the 20s RT_TA_F frequency of 18.91±3.35 Hz in the CEG according to Engin et al. (2020). Kim et al. (2015) found that muscle tone rises with exercise intensity, indicating that the higher physical activity level in the CEG[45], especially in the TA muscle, led to the observed increase in muscle tone.

The greater rise in TA and GCM_F in the CEG relative to the thigh muscles is due to the primary features of core activities. The five fundamental exercises mainly transfer forces to the muscles around the ankle joint in a closed kinetic chain fashion to enhance core stability and balance[11, 16]. Several studies have utilized CEs to improve ankle joint stability, attributing the greater alterations in muscle tone in the ankle joint area compared to other regions[46-48].

The study's limitations stem from the absence of gender analysis, as 23 healthy adults in their 20s were categorized into exercise and non-exercise groups without considering gender. No significant interaction effects were found for group and time factors during the 12-week period. Future study should focus on these constraints to achieve a more thorough understanding.

5. CONCLUSION

In conclusion, regulating muscle tone in healthy adults with well-timed and vigorous core workouts is advantageous. This can aid in avoiding harm to the lower extremity area during different core workouts.

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