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Full Title: Effects of Different Exercises on Respiratory Parameters: A Randomized Controlled Trial

Short Title: Effect of different exercises on respiratory

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Ethics approval

Permission for the study was obtained from KTO Karatay University Faculty of Medicine Drug and Non-Medical Device Research Ethics Committee with decision number 2020/024 and prospectively registered at www.clinicaltrials.gov (NCT04477915).

Effects of Different Exercises on Respiratory Parameters: A Randomized Controlled Trial

Abstract

This study was designed to compare the effects of core stabilisation and auxiliary respiratory muscle strengthening exercises on oxygen consumption and respiratory parameters. A total of 51 participants were divided into 3 groups with block randomization method according to age and gender: Core Stabilisation (CS) Group (n = 17), Auxiliary Respiratory Muscles Exercise (ARM) Group (n = 17) and Control (C) Group (n = 17). VO_2max, first second of forced expiration (FEV1)/Forced vital capacity (FVC), and maximal voluntary ventilation (MVV) values were evaluated before and after the study. CS and ARM strengthening exercises were applied 3 days a week for 6 weeks. The increase in the FEV1/VC values was higher in the CS and ARM groups than in the C group ($p<0.05$), whereas no statistically significant difference was observed between the ARM and CS groups ($p<0.05$). There was no statistically significant difference between the groups in terms of VO_2max values before and after the study ($p>0.05$). The increase in the MVV values was higher in the CS and ARM groups than in the C group ($p<0.05$), whereas no statistically significant difference was observed between the ARM and CS groups ($p>0.05$). CS and ARM exercises had positive effects on FEV1/FVC and MVV.

Keywords: exercise, maximal voluntary ventilation, isometric exercise, forced vital capacity, core stability

1. INTRODUCTION

Exercise or functional capacity refers to an individual's ability to perform submaximal activities requiring the integrated efforts and health of the pulmonary, cardiovascular and musculoskeletal systems (Arena et al., 2007). Maximum oxygen uptake (VO_2max) is a widely used indicator of human aerobic capacity (Trinschek et al., 2020) and refers to the maximum amount of O_2 used during an exercise that involves large muscle groups. The oxygen demand of the muscles resulting from increased exercise intensity is met by an increase in VO2max.This increase in oxygen demand occurs by resynthesis of ATP in the mitochondria during aerobic exercise (Santisteban et al., 2022).

Diaphragm is one of the core muscles and performs 2/3 of the pumping task during breathing. Core can be defined as a box formed by the abdominals, paraspinals, diaphragm and pelvic floor muscles located at the front, at the back, above and below, respectively (Karthikeyan, 2018). Core stabilisation exercises have been reported to improve respiratory parameters, muscle strength and physical fitness in different populations (Hung et al., 2019).

Respiratory muscles work like a pump, consuming 16% of O_2 during severe exercises. Thus, effective respiratory muscle strength is important in meeting exercise requirements. Respiratory muscles cause insufficient oxygen delivery to working muscles during exercise and can expose them to fatigue, limiting optimal working skills (McConnell, 2009). Fatigue or weakness of respiratory muscles has been reported to be significantly associated with exercise limitation in healthy individuals (Janssens et al., 2013).

Exercise increases the strength and endurance of respiratory muscles, contributes to the increase in lung volume and capacity and increases physical capacity (Bilici & Genç, 2020). The increase in inspiratory muscle strength may cause more negative pressure in the pleural space, increasing lung volume (Lutfi, 2017). Also, it improves the physical performance and oxygenation of the lungs, diaphragm and inspiratory muscles (Majewska-Pulsakowska et al., 2015). It seems appropriate to draw attention to the work of auxiliary respiratory muscles in sports education (Vašíčková et al., 2017), including the diaphragm, external intercostal muscles, the pectoralis major and minor, serratus anterior, latissimus dorsi, serratus posterior superior, sternocleidomastoid, infrahyoid and scalene muscles (Perenc et al., 2016).

The use of cardiopulmonary exercise testing is a common method in prescribing physical exercise and determining submaximal and maximum physical capacity (Herold et al., 2020). Aerobic exercise capacity can be performed with submaximal or maximal exercise tests, such as cycling and using the treadmill or arm ergometer. Oxygen uptake, carbon dioxide production and minute ventilation are determined instantly through gas analysis devices. Both O_2 and CO_2 concentrations for each breath can be found and VO_2max can be measured directly during the test.

Respiratory tests, such as forced vital capacity, inspiratory capacity, and maximal voluntary ventilation (MVV), can be performed using the simple spirometer, which is widely used for respiratory parameter measurement.

There is evidence in the literature that 2-8 weeks of exercise training improves VO_2max in untrained, overweight, obese, and healthy sedentary or recreationally active adult males and females (Milanović et al., 2015; Sloth et al., 2013). However, studies investigating the effects of exercises aimed at strengthening the accessory respiratory muscles on oxygen consumption and respiration are insufficient. However, to the best of our knowledge, we could not found any study comparing the effects of core stabilization exercises and strengthening the accessory respiratory muscles on oxygen consumption and respiratory parameters. This study aims to compare the effects of core stabilization exercises and strengthening the accessory respiratory muscles on oxygen consumption and respiratory parameters. It is assumed that both exercises have positive effects on oxygen consumption and respiratory parameters.

2. MATERIALS AND METHOD

2.1. Participants

Permission for the study was obtained from KTO Karatay University Faculty of Medicine Drug and Non-Medical Device Research Ethics Committee with decision number 2020/024 and prospectively registered at www.clinicaltrials.gov (NCT04477915). Healthy individuals between the ages of 18 and 25 were included in the study after obtaining written informed consent. All procedures were performed in accordance with the Declaration of Helsinki. The sample size of the study was determined with G * Power (G * Power Ver. 3.0.10, Franz Faul, Universität Kiel, Germany). It was calculated that at least 13 individuals should be included in each group to obtain 90% power with $\alpha = 0.05$ type I error in the study (Bostanci et al., 2019). Considering possible losses, 51 people were included in this study conducted between July and August 2020 in the laboratory of KTO Karatay University.

The participants were divided into three groups through the block randomisation method: Core Stabilisation (CS) Group (n = 17) (11 women, 6 men), Auxiliary Respiratory Muscles Exercise (ARM) Group (n = 17) (11 women, 6 men) and Control (C) Group (n = 17) (11 women, 6 men). All evaluations were blindly evaluated by the same researcher (KY) before and after the study. Core stabilisation exercises and auxiliary respiratory muscles exercises were applied by the same physiotherapist (BSU), 3 days a week for 6 weeks (Figure 1).

Figure 1 CONSORT flow diagram.

The exclusion criteria of this study were determined according to the criteria of The American College of Sports Medicine (ACSM) (Bayles, Madeline P.Swank, 2018):

- Those who had acute myocardial infarction
- Those who have unstable angina
- Those who have uncontrolled cardiac arrhythmias
- Those who have endocarditis
- Those who have various symptomatic aortic stenosis
- Those who have acute pulmonary embolism, pulmonary infarction, and deep vein thrombosis

- Those who have acute myocarditis and pericarditis
- Those who are not physically fit to perform the test safely

Participants were requested not to drink alcohol and not to smoke 24 and 2 hours, respectively, before the measurement. In order not to affect the results of the participants due to the training effect, no training was given about the test before the measurements.

2.2.Measurements

2.2.1. Maximum oxygen consumption (VO_2max)

VO_2max values of the participants were evaluated with the h/p cosmos mercury med (H/P cosmos sports & medical gmbh, Nussdorf-Traunstein, Germany) device using the Balke-Ware protocol before and after the study. The Balke-Ware protocol is a multi-step protocol consisting of steps for 1 minute that start at 0% in the first minute, at a rate of 91.1 $m \cdot min^{-1}$. The speed is maintained throughout the entire test, but the slope increases by 1% at every minute (Arena et al., 2007).

The test should be terminated when the maximum heart rate of 85% age predicted HRmax is reached (Bayles, Madeline P.Swank, 2018). ACSM criteria were complied with during testing (Bayles, Madeline P.Swank, 2018).

2.2.2. Pulmonary Function Tests

FEV1/FVC, VC and MVV values of the participants were measured using the Cosmed Fitmate Med (Cosmed The Metabolic Company, Italy) device before and after the study. A nasal plug and a disposable antibacterial mouthpiece were used during the measurements, as the participants sat on a chair with back support. Devices and equipment were disinfected after each participant. They were asked to perform three normal breaths, then to make a deep inspiration and finally to exhale for 6 seconds during the FEV1/FVC measurement. MVV measurement [l/min] was performed for a maximum of 12 seconds (Bernardi et al., 2014) for each participant where they were asked to make inspiration and expiration volitionally (Bayles, Madeline P.Swank, 2018). The evaluations were realised in three replicates and the best acceptable test results were recorded. Tests were carried out in accordance with ACSM criteria (Bayles, Madeline P.Swank, 2018).

2.2.3. Exercises

Plank, side plank, bridge, swimmer, and flutter kick exercises were applied to the core stabilisation group (Table 1) (Figure 2). Under the guidance of a physiotherapist, exercises were performed three days per week for six weeks (Jamison et al., 2012), getting harder with each repetition: two sets of 25 seconds in the first two weeks, two sets of 30 seconds in the third and fourth weeks, and three sets of 35 seconds in the fifth and sixth weeks (Turna, 2020).

Table 1 Core Stabilisation Exercises

Figure 2 Core Stabilisation Exercises

Progressive maximal volitional isometric exercises were performed on the upper trapezius, scalene, sternocleidomastoid, serratus anterior and pectoralis major muscles of the Auxiliary Respiratory Muscles Exercise Group under the supervision of a physiotherapist for 3 days a week in 6 weeks. The exercises were applied as three sets of ten repetitions in 10 seconds with a 90-second rest between sets (Space & Taylor, 2014). The Control Group continued their daily routine for 6 weeks.

2.3.Statistical analysis

The SPSS 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) statistical package program was used to evaluate the data. The conformity of variables to normal distribution was examined using the Shapiro-Wilk test and histogram method. Paired-samples t-test were used to compare the parameters between the pre-treatment and post-treatment measurements. One-way ANOVA was used to test differences among the groups at the same time interval. Tukey post-hoc tests were used for multiple comparisons. The effect size was calculated using the equation proposed for Cohen' d (Cohen, 2013). The level of significance was set at $p<0.05$.

3. RESULTS

3.1.Demographic information

The age, gender and BMI values of the participants were recorded (Table 2).

Table 2 Demographic data

3.2.Maximal oxygen uptake and respiratory parameters

The differences in VO_2max values before and after the study were similar between the groups. ($p>0.05$) (Table 4).

The difference in FEV1/FVC ratios before and after treatment improved in the CS group ($p<0.01$, $d=2.27$) and ARM group ($p<0.01$, $d=3.29$) (Table 3). While there was a greater increase in FEV1 / FVC values in CS and ARM groups compared to C group ($p<0.05$), no statistically significant difference was found between the ARM group and the CS group ($p>0.05$) (Table 4).

Improvements were found in MVV values before and after treatment, in the CS group ($p<0.01$, d:1.42) and in the ARM group ($p<0.01$, d:2.95) (Table 3). While there was a greater increase in FEV1 / FVC values in CS and ARM groups compared to C group ($p<0.05$), no statistically significant difference was found between the ARM group and the CS group ($p>0.05$) (Table 4).

Table 3: Comparative results of pre- and post-treatment evaluation parameters of the groups

Table 4: Intergroup Comparison of Differences in Respiratory Values Before and After Study

4. DISCUSSION

While core stabilization exercises and auxiliary respiratory muscle exercises had no effect on VO_2max in healthy young individuals, it was determined that they increased MVV and FEV1/FVC. It was found that auxiliary respiratory muscle exercises were more effective than core stabilization exercises in increasing MVV and FEV1/FVC.

VO_2max is one of the most important indicators of aerobic capacity and endurance. Pre-study VO_2max values in all three groups were similar in this study. No difference in VO_2max values between the groups was noted after performing the exercises for 6 weeks. Mackala et al. (2020), applied randomised controlled study on 16 young football players. Inspiratory muscle training was performed by a group for 8 weeks in addition to pre-season training in their study. The control group continued only the pre-season training. The results showed that the group performing inspiratory muscle training in addition to pre-season training had a statistically significant difference in their VO_2max values compared with the Control Group. Çiçek et al. (2018), conducted their studies on 40 female participants. They were divided into two groups: Group Aerobic-step and Group Core Exercise. Both groups applied the exercises 4 days a week for 12 weeks. Their respiratory tests and VO_2max values were recorded before and after the study. At the end of the study, a significant difference in terms of VO_2max values in favour of core stabilisation exercises was noted.

The VO_2max results of this study differ from that of the literature. We think that this fundamental difference is due to the study periods. In light of prior studies, we concluded that a 6-week exercise period used in this study was short and did not significantly raise VO2max values. In addition, we think that an aerobic training program should be performed rather than strength training in order to increase VO_2max.

As compared with the Control Group, an increase in the FEV1/FVC ratio was found in the core stabilisation and auxiliary respiratory muscle exercise groups after the exercises in this study. There was no difference at Group Core Stabilisation and Group Auxiliary Respiratory Muscles Exercise. Rahimi et al. (2019) conducted a study on 26 sedentary male students with poor posture performing dynamic neuromuscular stabilisation exercises 3 days a week for 6 weeks, wherein participants underwent applied respiratory function tests before and after the study. At the end of the study, they showed that dynamic neuromuscular stabilisation exercises increased FEV1/FVC and MVV values in students with poor posture. In another study, Tong et al. (2016), divided 16 recreational jogging participants into two groups, Exercise Group and Control Group, in their study for 6 weeks. While the Control Group performed high-intensity interval training, the Exercise Group performed core stabilisation and inspiratory muscle training in addition to high-intensity interval training. Respiratory parameters of the participants were evaluated before and after the study. At the end of the study, they found a statistically significant difference in FEV1/FVC and MVV values between the Exercise Group and the Control Group. The results of both studies are similar to this study. In this regard, this study supports the literature. Long-term exercises not only help increase the strength of the respiratory muscles, but also lead to better physical fitness and respiratory function (Çiçek et al., 2018). As a result, engaging in specific sports or physical activities can help to strengthen the respiratory muscles, improve lung capacity, and achieve effective lung function (FVC, FEV1). Similar to the literature, it shows that the 6-week exercise program used in this study is effective in increasing respiratory functions.

In this study, there was a difference in MVV values between the groups after exercise. While there was no difference between Core Stabilisation and Auxiliary Respiratory Muscles Exercise Groups, MVV values in both exercise groups increased compared to the Control Group. Bernardi et al. (2014), in their study applied respiratory muscle endurance training to the Exercise Group of 20 triathletes every day of the week for 5 weeks. They performed cardiopulmonary tests before and after the study. At the end of the study, they found a statistically significant difference in the MVV value between the triathletes who performed respiratory muscle endurance training and the Control Group. The results are consistent with this study. Better respiratory muscle coordination and strength, as well as lower airway resistance, are indicated by higher MVV values (Surekha et al., 2016). However, the present study indicates probably developed respiratory muscle strength and coordination and better oxygen availability lead to increase the MVV.

The results of this study were generally similar to the literature. We used isometric exercises in this study to strengthen the auxiliary respiratory muscles. Although it was observed that inspiratory muscle training was generally used in the literature, there were differences within each study such as the methods used in core stabilisation.

The strengths of our study were the use of objective methods in the measurements and the sample size. The limitation of this study was that the long-term effects of the exercises were not followed up.

There is no study comparing the effects of core stabilisation exercises and auxiliary respiratory muscle exercises on VO_2max, MVV and FEV 1/FVC in the literature. We have seen that exercise programs applied to increase these values affect core stabilisation and auxiliary respiratory muscle based on the results of this study. However, considering that these exercises have no superiority to each other, we think that both exercises will have the same result.

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CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

Data are available on request from the authors.

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Table 1. Core Stabilisation Exercises

Exercise	Description
Plank	It is started in the plank position (i.e., prone position with the forearms and toes on the ground). Elbows are directly under the shoulders and forearms point forward. The head should be relaxed and facing the ground. By working the abdominal muscles, the

	belly is pulled towards the spine. The chest is kept straight and firm, and the body is kept in a straight line from the ears to the toes without drooping or twisting. This is the neutral spine position. The heels should be over the toes.
Side plank	Start from the side with the feet and one forearm directly under shoulder. Activate the belly muscles, and the hip is raised until the body is in a straight line from head to toe. During the time allotted for each set, the position is held without letting the hip drop and then repeated on the other side.
Bridge	Before pushing up, the waist is pushed to the ground, and the abdominal and hip muscles are tightened. The hips are raised so that the knees form a straight line up to the shoulders. The core is tightened, and the umbilicus is pulled back towards the spine. Wait 20–30 s, and then, return to the starting position.
Swimmer	Lie down on the abdomen with the legs straight together. The arms are extended straight above the head with the shoulders resting on the back and away from ears. The abdominal muscles are pulled inwards, so the umbilicus is lifted off the ground. The arms and legs are extended in the opposite directions that they naturally lift off the ground. Simultaneously, the spine is extended so that the head is raised from the mat as an extension of the spine reach. Continuing to reach from the centre, the right arm and left leg are pumped up and down with a small blow. Alternate right arm/left leg and left arm/right leg strokes. Inhale for 5 kicks and stretches

	and exhale for up to 5 exhalations. This should feel like swimming in a pool. Repeat 2–3 cycles for 5 breaths.
Flutter kick	Both hands are placed under the hips. The right leg is raised slightly higher than hip height, while the lower back is kept on the ground and the left leg is lifted a few inches above the ground. Hold for 2 s, and then, change the position of the legs to make a slam kick motion.

Table 2. Demographic data

	CS (M ± SD)	ARM (M ± SD)	C (M ± SD)	*P*-value
Age (Year)	19,94 ± 0,74	19,76 ± 0,66	19,82 ± 0,80	.781
BMI (kg/m^2)	20,74 ± 2,88	21,75 ± 2,34	23,17 ± 3,17	.050*

*p<0.05, BMI, body mass index; M, mean; SD, standard deviation; CS, core stabilisation; ARM, auxiliary respiratory muscle; C, Control, Anova

Table 3. Comparative results of pre- and post-treatment evaluation parameters of the groups

	CS (n=17)			ARM (n=17)			C (n=17)		
	Before	**After**	**p**	**Before**	**After**	**p**	**Before**	**After**	**p**
VO_2max (mL/kg/min)	27.67 ± 4.65	28.18 ± 5.77	0.708	28.42 ± 4.37	25.47 ± 6.74	0.112	30.21 ± 8.76	27.57 ± 6.06	**0.043**
FEV1/FVC	87.96 ± 4.86	90.74 ± 4.65	**<0.01**	86.92 ± 3.37	88.76 ± 3.48	**<0.01**	85.34 ± 4.40	85.61 ± 4.01	0.427
MVV (L/min)	120.58 ± 30.42	136.56 ± 28.06	**<0.01**	120.90 ± 22.61	130.25 ± 22.53	**<0.01**	101.47 ± 39.82	100.25 ± 44.55	0.769

*p<0.05, VO_2max, maximum oxygen uptake; MVV, maximal voluntary ventilation; FEV1, first second of forced expiration; FVC, forced vital capacity; MD, mean difference; CS, core stabilisation; ARM, auxiliary respiratory muscle; C, Control, Paired sample t test

Table 4. Intergroup Comparison of Differences in Respiratory Values Before and After Study

		VO_2max		MVV		FEV1/FVC	
		MD	*P*-value	MD	*P*-value	MD	*P*-value
CS	**ARM**	1.95	0.559	7.2	0.190	7.20	0.190
	C	4.02	0.095	17.2	**<0.001****	17.2	**<0.001****
ARM	**CS**	−1.95	0.559	−7.2	0.190	−7.2	0.190
	C	2.07	0.522	9.99	**0.046***	9.99	**0.046***
C	**CS**	−4.02	0.095	−17.2	**<0.001****	−17.2	**<0.001****
	ARM	−2.07	0.522	−9.99	**0.046***	−9.99	**0.046***

*p<0.05, **p<0.01 VO_2max, maximum oxygen uptake; MVV, maximal voluntary ventilation; FEV1, first second of forced expiration; FVC, forced vital capacity; MD, mean difference; CS, core stabilisation; ARM, auxiliary respiratory muscle; C, Control, Anova, Tukey.

Table 5. Differences in Respiratory Values Before and After the Study

		VO_2max		MVV		FEV1/FVC	
		MD	*P*-value	MD	*P*-value	MD	*P*-value
CS	**ARM**	1,95	,559	7,2	,190	7,20	,190
	C	4,02	,095	17,2*	,000*	17,2*	,000*
ARM	**CS**	−1,95	,559	−7,2	,190	−7,2	,190
	C	2,07	,522	9,99*	,046*	9,99*	,046*
C	**CS**	−4,02	,095	−17,2*	,000*	−17,2*	,000*
	ARM	−2,07	,522	−9,99	,046*	−9,99*	,046*

*p<0.05, VO_2max, maximum oxygen uptake; MVV, maximal voluntary ventilation; FEV1, first second of forced expiration; FVC, forced vital capacity; MD, mean difference; CS, core stabilisation; ARM, auxiliary respiratory muscle; C, Control, Anova, Tukey.

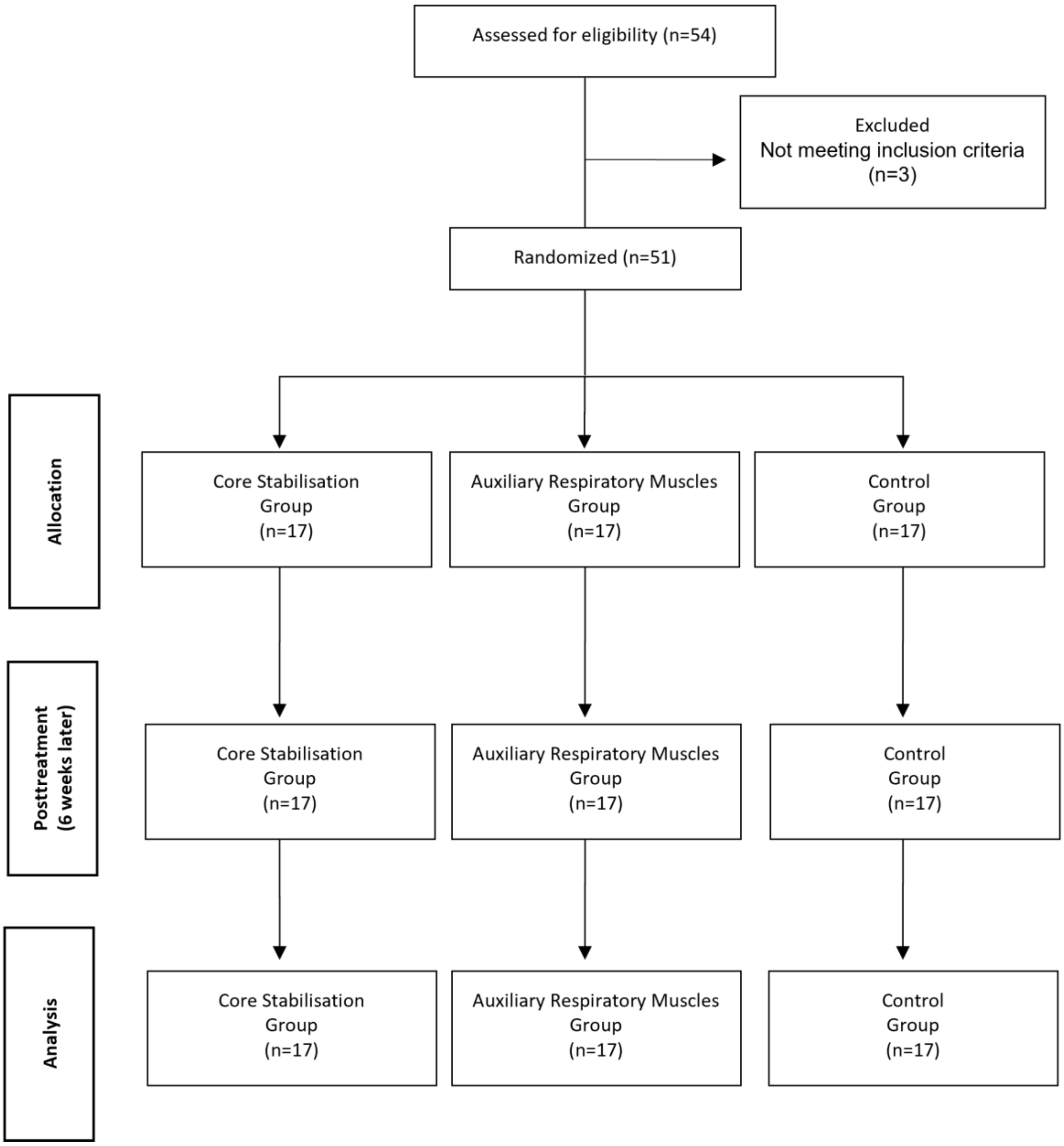

Figure 1 CONSORT flow diagram.

Figure 2 Core Stabilisation Exercises (a: Plank, b: Side Plank, c: Bridge, d: Swimmer, e: Flutter kick)