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Analysis of the Effects of Double Straight Leg Raise and Abdominal Crunch Exercises on Core Stability

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Abstract: *Core training often involves engagement of the abdominals and plays an important role in rehabilitation, health promotion, and improvement of sports performance. Crunches and straight leg raises which are commonly employed in training the abdominal muscles. This study examined the effects of combining double straight leg raise and abdominal crunch exercises on core strength, endurance and flexibility.27 participants were recruited (13 males and 14 females)which comprised of three exercise groups [abdominal crunch group (ACG), double straight leg raise group (DSLG) and a combination group (ACG+DSLG)]for a period of six weeks. Pre and post-intervention parameters of core strength, endurance, and flexibility were measured. Paired sample t-test and ANOVA were used to test for differences within and between groups respectively.Within groups analysis showed significant improvements in all outcomes among the ACG+DSLG for core flexibility (0.004), endurance(0.021) and strength (0.004). Flexibility (0.046) improved within the ACG while the DSLG improved in flexibility (0.017) and strength (0.030).This study suggest that during core rehabilitation, abdominal exercise programs involving the recruitment of both the upper and lower abdominal muscle groups may be better in improving core stability.*

Keywords: *Abdominal crunches, core, double, endurance, flexibility, stability, straight leg raise, strength.*

I. INTRODUCTION

Core stabilization is the muscular control required around the lumbar spine to maintain functional stability [1]. The stabilization of the trunk is necessary for the spine and the pelvis to increase stability, improve muscle strength, and to adjust muscular motion and balance during general body movement [2]. Contraction of the core muscles keeps the spine in its most stable position, the neutral zone [1]. This contraction occurs prior to any limb movement to keep the core of the body rigid during all movements [3,4]. A comprehensive strengthening or facilitation of these core muscles enhances athletic performance, prevents and rehabilitates various lumbar spine and musculoskeletal disorders [1].

Core stability refers to the ability of the "core" muscles to stabilize the lumbar spine and pelvic girdle when involved in static postures and dynamic motions [5]. This involves the ability of the lumbopelvic hip complex to prevent buckling and to return to equilibrium after perturbation [6]. Components of core stability include strength, endurance, flexibility, motor control, and function [7]. Core endurance is the ability to maintain a position or perform multiple repetitions,[8] while core strength relates to the muscles' ability to produce force through contractile force and intra-abdominal pressure.[9] Flexibility refers to the range of motion possible around a specific joint or a series of articulations.[10].Weakness of the core causes alterations in the transfer of energy, resulting in reduced sport performance and risk of injury to the weak or underdeveloped muscle group. It has therefore been suggested that strong extremities with a weak core results in a decrease in the muscular summation through the core and will result in less force production and inefficient movement patterns [11].The coordination of muscle activity around the lumbopelvic region is therefore vital to the generation of mechanical spinal stability [5] and the abdominal muscles are primarily involved in controlling the position of the spine and pelvis [11].

Individuals with poor endurance of the abdominal and back muscles will benefit from appropriate use of core stabilization exercises like bridging, crunch, leg raises, side-bridging, prone bridging on elbows and toes, and the quadruped arm/lower extremity lift exercises [12], depending on the individual needs of a patient or athlete [12]. Increasing trunk stability is considered one of the most important functions of the abdominal muscles [13]. Promotion of this stabilizing role should be a prime consideration when designing abdominal exercise programs [13].

Abdominal exercises are prescribed for both the prevention and treatment of low back injury. The abdominal crunch and straight leg-raise are popular abdominal exercises performed by the general and athletic populations for the benefits of improving fitness, sport performance, and core muscle function [14]. They are among the most common exercises being used for strengthening the abdominal muscles [15]. The crunch is considered a principal exercise for working the abdominal musculature [14]. It consists of flexing the spinal column approximately 30 degrees from the lying down position with knees flexed and feet fixed (by a person) in place [16]. Greater activity of the superior portion of the rectus abdominus (RA) muscle has been reported in exercises flexing the spinal column" [17].

The straight leg-raise abdominal exercise involves lying supine on the floor and lifting up the legs until the upper thighs touch the lower abdominals. The feet are kept off the ground through the exercise [18]. Straight leg-raise in the supine position targets the lower rectus abdominis muscle [15]. Although abdominal strengthening exercises can differentially activate various abdominal muscle groups [19], there is paucity of evidence supporting the use of one core stability exercise over the other [5]. Partial curl-ups (crunches)were reported to have generated the highest muscle challenge-to-spine cost indices in an Electromyographic study conducted by [20] but no single exercise was found that optimally trained all of the abdominal muscles. It was concluded that a variety of selected abdominal exercises are required to sufficiently challenge all of the abdominal muscles and that these exercises will-differ to best meet the different training objectives of individuals. Therefore, this study set out to compare the effect of the isolated administration of double straight leg raises and abdominal crunch exercises to the effect of combining both abdominal exercises for improved core endurance, strength and flexibility.

II. Materials and methods

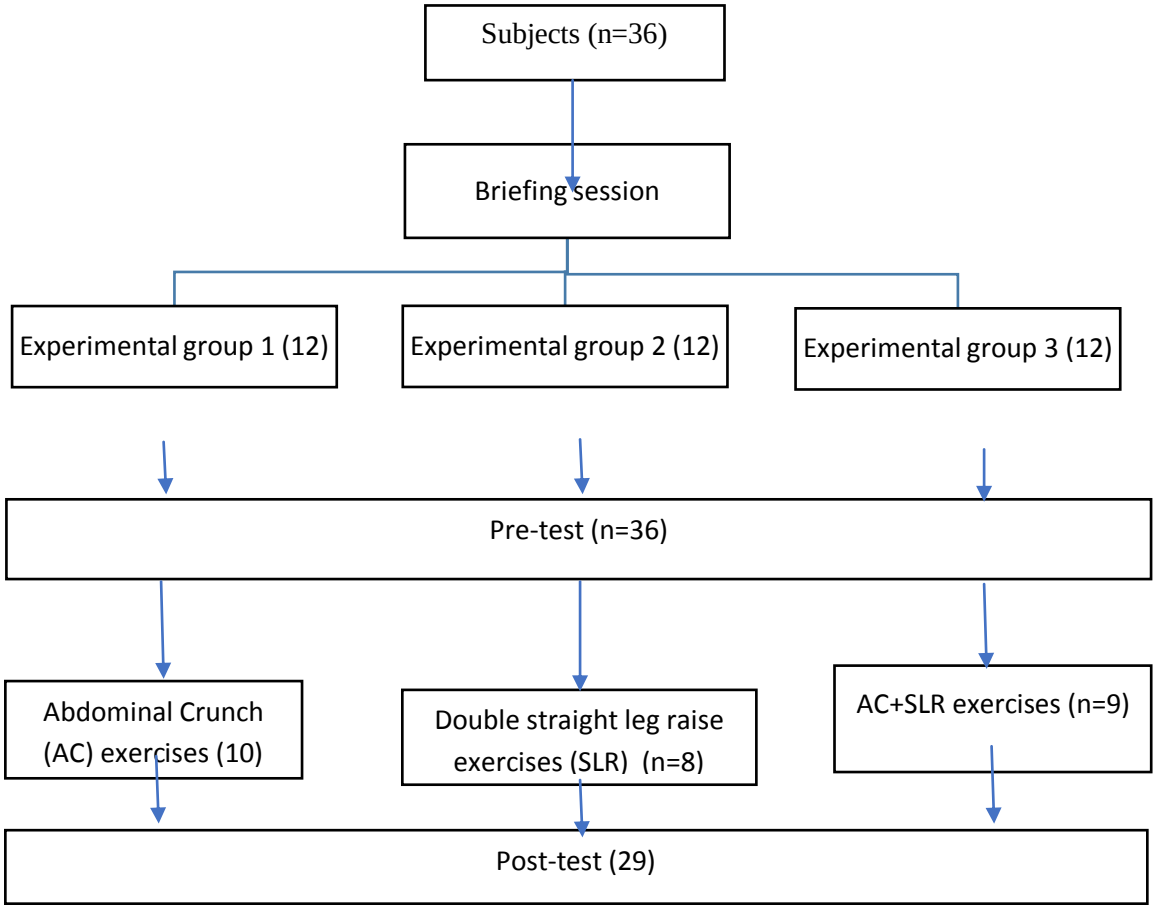
2.1 Participants

A total of 36 untrained apparently healthy students of the Department of Medical Rehabilitation, University of Nigeria Enugu Campus (UNEC), aged between 18 and 30years were recruitedfor this study but only 27 completed the post-test (13 men and 14women). All participants were free from any known cardiovascular and orthopedic problems. Subjects were also excluded if they had a history of acute or chronic back pain or if they could not complete the prescribed exercises.The study was approved by the Health Research and Ethics

Committee of University of Nigeria Teaching Hospital (UNTH), Ituku/Ozalla, Enugu State. Physical activity readiness questionnaire was completed and written informed consent was obtained from the participants prior to participation in the study.

2.2 Study Design

This study utilized a pre-test post-test (repeated measures) experimental design. In order to compare the effects of double straight leg raise and abdominal crunches on core strength, endurance and flexibility, participants completed a 6-week core exercise training program. Participants did not engage in any other core specific exercises during the 8-week period of this study. The flowchart of the experiment is presented in Fig 1.



2.3 Procedure

All participants were required to attend a briefing session before the pre-test. The weight in kilogram (kg) and height in meters (m) of all the participants were measured and BMI (body mass index) was calculated and the age of the participants were also recorded. Simple Random sampling technique (balloting without replacement) was used to assign the participants into three different groups, each of the participants was asked to pick a piece of paper with one of the following inscriptions **AC**– Abdominal crunch (Fig. 2), **DSLR** – Double Straight Leg Raise (Fig 3), **AC+DSLR** –Combination group. Participants completed a three-minute warm-up exercise by walking at a self-selected pace up and down a levelled surfaced hallway before commencing the pretest.The pre-

test involved core strength, endurance and flexibility testing to obtain baseline data. Core strength was tested using isoinertial strength test. It is a timed sit-up test, with the objective of performing as many full sit-ups as possible within one minute. This sit-up test protocol was developed by American Alliance of Health, Physical Education, Recreation, and Dance[22]. The test was initiated in the hook-lying position, with the participant's arm held across the chest, knees flexed at 90°, and feet secured. To complete a full sit-up, the participant's scapula touched the mat in the lying position and in the upright position, the elbows made contact with the knees.

Core endurance was assessed using trunk flexion endurance test. The test started with the subject in a hook-lying position with the trunk supported manually with a wedge angled at 60 degrees of trunk flexion. With the aid of a goniometer, the hips and knees were flexed to 90 degrees. The feet were secured with a strap. The arms were folded across the chest with the hands placed on the opposite shoulder. Subjects were instructed to hold the isometric posture as the wedge was removed. Time started when the wedge was moved backwards, and the participant held the isometric posture for as long as possible. Time stopped when any part of the participants back touched the wedge. The test was scored individually. Time was recorded in seconds, (to the nearest 0.1 sec)[23]. This protocol for theflexor endurance test as established by McGill, Childs, and Liebenson[24] targets the major trunk flexor, the rectus abdominis, which is a "global" muscle[23].

Active range of motion measurements was used as the trunk flexibility assessment based on Norkin and White[25].The trunk extension range of motion was measured by first recording the distance between C7 cervical vertebra and S1 sacral vertebra while standing upright. The participant was then asked to bend backward as far as possible with the pelvis stabilized. The distance between C7 and S1 was measured again and the length decrease was documented as the trunk flexibility.

Double straight leg raise and abdominal crunch exercises were administered 3 days a week for a period of 6weeksas shown in Table 1 below. Participants in the combination group received both exercises.

Table 1
Protocol for Double Straight Leg Raise and Abdominal Crunch Exercises

	1st Wk	2nd Wk	3rd Wk	4th Wk	5th Wk	6th Wk
Repetitions/Sets	8/1	8/1	10/1	10/1	12/1	12/1
Intensity	4secs	6secs	8secs	10 secs	12secs	14secs

Figure 2: abdominal crunches.

Figure 3: double straight leg raise.

2.4 Data analysis

Data was analyzed using Statistical Package for Social Sciences (SPSS), version 20. The data collected were analyzed using descriptive statistics of mean, standard deviation, frequency and percentages to summarize the data. Paired sample t-test was used to test for differences within the groups. Analysis of Variance (ANOVA) was used to test for significant difference between groups. Level of significance was set at α (alpha) = 0.05.

III. Results

Table 2shows the physical characteristics of the participants. A total of 27 participants completed the study, 10 were in the abdominal crunch exercise group (AC), 8 in the double straight leg raise exercise group (DSLR) and 9 in the combination group (AC+DSLR). The participants' age rangedfrom 18-30 years with a mean age and BMIof 23.26±2.80years and 23±1.75kg/m^2respectively. Table 3 shows the paired T-test of the difference in mean within the abdominal crunch exercise group. In the AC, analysis of the pre-test and post-test mean scores showed a significant difference only in core flexibility (p=0.046). Table 4 shows the paired T-test analysis of the difference in mean within the DSLR. In the DSLR, analysis of the pre-test and post-test mean scores showed significant differencesin core strength (p=0.030)and flexibility (p=0.017) only. Table 5 shows the paired T-test analysis of the difference in mean within the AC+DSLR. In the AC+DSLR, analysis of the pre-test and post-test mean scores showed no significant differencesin core strength(p=0.004), endurance (p=0.021) and flexibility (p=0.004). Table 6 shows the analysis of variance across the three groups. There was no significant difference in core strength (p=0.236), endurance(p=0.869) and flexibility (p=0.587).

Table 2

Physical characteristics of participants (n=27)

Variables	Minimum	Maximum	Mean	Standard Deviation
Age (yrs)	17	28	23.26	2.80
Weight(kg)	51.50	86	64.20	8.11
Height (m)	1.43	1.91	1.66	0.11
BMI (kg/m^2)	20.31	26.25	23	1.75

BMI= Body Mass Index, SD= Standard Deviation

Table 3

Paired T-test Analysis of the Pre and Post Strength, Endurance and Flexibility of the AC (n=10)

Variables	Pre	Post	t-value	P-value
Flexibility	6.89 ± 2.52	8.89 ± 2.89	2.353	0.046*
Endurance	65.33 ± 53.51	105.56 ± 102.60	2.088	0.070
Strength	19.44 ± 12.86	21.00 ± 6.71	0.670	0.522

*= Statistically Significant

Table 4

Paired T-test Analysis of the Pre and Post Strength, Endurance and Flexibility of DSLR (n=8)

Variables	Pre	Post	t-value	P-value
Flexibility	6.44 ±2.74	9.67 ±3.35	2.991	0.017*
Endurance	82.67 ±39.02	126.44 ±69.46	1.825	0.105
Strength	22.11 ±5.04	28.22 ±9.04	2.630	0.030*

*= Statistically Significant

Table 5

Paired Sample t-test Analysis within the Combined Group (AC+DSLR) (n=9)

Variables	Pre	Post	t-value	P-value
Flexibility	6.11 ±1.83	8.22 ±1.98	3.919	0.004*
Endurance	77.22 ±92.41	102.55 ±98.57	2.873	0.021*
Strength	19.78 ±8.79	24.89 ±8.01	3.912	0.004*

*= Statistically Significant

Table 6

Analysis of Variance Comparison of the Strength, Endurance and Flexibility across Groups (n=27)

Variables	Flexibility	Endurance	Strength
AC	2.00 ±2.55	40.22 ±57.78	1.56 ±6.97
DSLR	3.22 ±3.23	42.33 ±72.36	6.11 ±6.97
AC+DSLR	2.44 ±1.42	29.56 ±19.31	6.78 ±4.02
f-value	0.545	0.142	1.536
p-value	0.587	0.869	0.236

IV. Discussion

Core strength and endurance did not significantly improve in the AC.This result is not consistent with the findings of a previous work by Gauri, Vinod & Prajakta, (2011),that reported significant differences in core endurance with administration of curl ups. This differencemay be because trunk extensor exercises were administered alongside curl up exercises 5 days per week for a period of 5 weeks.Moraes et al (2009) had also suggested that for young, healthy and physically active adults which is the populationincluded in this study, when the objectiveis progression in the training process of abdominal force, the option ought to be for changes of loadsuperior to 20% of the 1-RM. This may also explain the insignificant difference recorded in the AC.The increase in flexibility of the trunk extensors reported in theAC even with the increase in the contraction of the anterior abdominal wall muscles (rectus abdominis and internal obliques) may be as a result of co-contraction, synergy and antagonistic properties of the trunk extensor muscles.

Significant improvements were recorded in core strength and flexibility with DSLR. This is in line with the findings of aprevious EMG study that showed that bilateral leg raise exercises elicited greater than 45% of MVC in the Rectus Abdominis and the Internal Oblique muscles [21]. It has also been reported that EMG signal amplitude greater than 45% MVIC on average may provide sufficient stimulus for strength gains in trunk musculature [22]. In accordance with another previous study, bilateral leg raise exercises are adequate for strengthening the abdominal muscles especially with internal oblique and rectus abdominis muscles [23,24]

AC+DSLR significantly improved core strength, endurance and flexibility. Guamares et al (1991) found significant differences between the EMG activity rectus abdominis with exercises targeted at the upper and lower abdominal muscles.AC activates the rectus abdominis, internal and external obliques [26]. Considering that abdominal strengthening exercises can differentially activate various abdominal muscle groups [27], it is expected that a combination of these exercises will yield greater improvements in core stability. This is consistent with the report of [28] that suggested that a variety of selected abdominal exercises are required to sufficiently challenge all of the abdominal muscles and that these exercises will-differ to best meet the different training objectives of individuals. However, this combination of exercises targeted at the upper and lower abdominal muscles did not yield significantly different benefits to the measured components of core stability when compared to the administration of those exercises in isolation. No significant differences were recorded in core strength, endurance and flexibility across the groups. The findings of this study also differs from the findings of Kim & Lee [29] which stated that for the activation of the upper and lower rectus abdominis and the external oblique, the sit-up (an exercise that flexes the spinal column) which is similar to abdominal crunches was found to be more effective than the straight leg-raise.

V. Conclusion

The findings of this study suggest that during core rehabilitation, abdominal exercise programs involving the recruitment of both the upper and lower abdominal muscle groups may be better in improving core stability. Further studies are however recommended on the effects of exercises targeted at the upper and lower abdominal muscle groups.

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