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Manuscript Title: The effect of an 8-week fitness regime on low back pain and core strength in high-risk professionals.

Running title: Core fitness in high-risk professionals.

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ABSTRACT

Background: Low back pain is prevalent among various populations and greatly impacts their quality of life. Professions that incorporate several working hours combined with heavy labor are the most affected. This study intends to examine the effects of an 8-week core training intervention in emergency personnel.

Methods: Sixteen randomly selected male participants; police officers (n = 8) and firefighters (n = 8) (mean age: 40.75 years; mean height: 177.69 cm; mean body mass: 85.50 Kg) performed various testing procedures that assessed core muscle strength and endurance, and filled the Oswestry disability index questionnaire regarding the level of low back pain before and after the intervention. The 8-week intervention consisted of two 45-60-minute sessions per week that included ten core-related exercises.

Results: Statistical analysis; paired samples t-test and Wilcoxon signed-rank test, demonstrated significant effects in the 30sec sit-up test, the Double Leg Lowering Test and the isometric abdominal strength measurements; p value level of significance was set at $p \leq 0.05$. All participants had minimal lower back disability before and after the intervention.

Conclusions: The results demonstrated that the prescribed regime could improve core strength and endurance in high-risk professionals. The most important finding is that training interventions for emergency personnel are most effective when they incorporate a variety of exercises that target the core musculature in all planes of movement and engage the whole range of motion.

Keywords: Abdominal muscles, Muscle strength, Physical exercise, Isometric exercise, Physical fitness.

INTRODUCTION

Low back pain (LBP) is an issue that troubles a large percentage of the population¹. LBP is the second most common disability disorder amongst young adults in the USA². A systematic literature review by Hoy et al.³ reviewed 165 studies on the global prevalence of LBP; point prevalence was measured at 11.9%, and one-month period prevalence was found to be 23.2%. Chronic LBP has a detrimental effect on socioeconomic status and negatively impacts people's careers⁴. The literature argues that no particular factor causes the onset of LBP and that it may unfold from any of the various anatomical structures of the human body⁵.

Additionally, risk factors for LBP onset are challenging to determine due to the variations in the study populations, research methodologies and case definitions used throughout the vast bibliography. The risk factors most commonly associated with LBP are age and gender, as women are more prone to degenerative disease⁶. Furthermore, increased body mass index and obesity, anxiety, depression and stress have been found to be risk factors for the onset of LBP⁶.

Some occupations are more prone to LBP onset and progression than others since they require a lot of working hours in awkward positions. For example, police officers and firefighters are exposed to increased physical stress related to occupational tasks such as handling heavy weights, prolonged standing and trunk flexion and rotation⁷. The prevalence of chronic LBP in Brazilian federal highway police officers was measured at 67%, and median pain intensity was 3.0 (IQR = 0-5). What is more, chronic LBP and high pain intensity were more frequently present in policemen who had served in the force for more than 11 years⁷. An extensive study involving nine police organizations and a total of 3,589 police officers found chronic LBP prevalence to be 28.7%. Additionally, police officers who reported chronic LBP vs those who reported LBP symptoms in the last 12 months had a higher reduction in work-related activities (64.4% vs 45.7%), higher loss of working days (11.9 ± 43.5 vs 1.5 ± 9.8), higher percentage of health care visits related to LBP (86.2% vs 64.2%) and more use of pain medication (90.1% vs 69.7%), in the last 12 months⁸. A study by Burton et al.⁹ examined the onset and progression of LBP in police officers who wear 8.5kg body armor compared to officers who do not. Occupational risk for LBP onset was increased by wearing body armor and exposure to prolonged hours of driving. Additionally, more years of service in the force and stress related to police work were interrelated with the reoccurrence of LBP episodes and the progression to a chronic problem.

A recent systematic review and meta-analysis on global prevalence of six different musculoskeletal disorders (MSDs) in firefighters revealed that LBP is the most prevalent one, measured at 31%. The second most prevalent MSD, the lower extremities, was measured at 16%, which makes it only half as prevalent as the LBP¹⁰. Peate et al.¹¹ demonstrated that firefighters share similar characteristics to police officers, and that following a two-month core muscle-strengthening training program decreases the number of injuries by 42%, by enhancing core and/or back stabilizing muscle strength and flexibility. Further research on individuals suffering from chronic LBP revealed that exercising improves functionality, reduces pain and increases mobility. The literature agrees that any form of physical fitness training could benefit individuals with LBP. Particularly isokinetic¹², motor control, segmental stabilization, core stabilization, and trunk balance pieces of training effectively alleviated chronic LBP¹³. Nevertheless, there is a need for exercise regimes that are specifically tailored to the professional and physical demands of emergency personnel in order to promote fitness and minimize injuries¹⁴.

The main reason firefighters avoid exercising is the common belief among them that exercising might lead to an injury due to inadequate physical fitness, overtraining and/or incorrect execution of a certain exercise¹⁵. However, the literature provides enough evidence to emphasize the need for more prevention regimes that tackle chronic LBP and better workplace management programs for police officers and firefighters. Thus, this study aims to examine whether an eight-week training intervention can improve core strength and endurance while alleviating low back pain, if present, in police officers and firefighters. The authors hypothesize that a training intervention will have significant benefits on core strength and alleviation of LBP in police officers and firefighters.

MATERIALS and METHODS

Participants and Design

This study investigated the effects of an 8-week core strengthening and stability intervention on the trunk muscle performance of police officers and firefighters and its impact on low back pain. The testing procedures assessed the core musculature's strength, stability and flexibility, including the level of LBP before and after the 8-week intervention. Sixteen male individuals were randomly selected to participate in the study; eight police officers and eight firefighters (age: 40.75 ± 8.51 years; height: 177.69 ± 6.28 cm; body mass: 85.50 ± 10.87 Kg) (see Table I for more information). The only eligibility criterion was that all participants had

to be active in either of the two occupations. All of them had to sign an informed consent form, before any testing procedure could commence. In addition, the participants completed the Oswestry Disability Index (ODI) (disability score: $7.00 \pm 7.12\%$) and the International Physical Activity Questionnaire (IPAG) (fitness level: $7.38 \pm 6.38 \text{Hours} \cdot \text{Week}^{-1}$). The former is the "golden standard" measurement of permanent functional disability in the lower back. At the same time, the latter is usually completed to quantify an individual's fitness level and health-related physical activity, measured in hours of physical activity per week¹⁶. The participants were instructed to avoid any physical training for the 24 hours preceding each testing session to avoid fatigue and potential delayed onset muscle soreness that could affect the testing results. Still, participants were encouraged to continue their regular training regimes during the eight-week intervention period if they wanted to. No specific dietary instructions were provided. The Cyprus ethical committee approved this study.

** Place Table I here **

Procedures

Warm-up and preparation. Before any testing procedure, the RAMP warm-up was initiated¹⁷. Firstly, each participant cycled on an ergometer cycle (model 894E, Peak bike, MONARK, Varberg, Sweden) for five minutes at a moderate intensity. Following that, the participants performed a series of dynamic stretching exercises that included: good mornings, side crunches, hip circles, cross jacks, bent-over twists and wood choppers for 10-12 repetitions each. The testing phase was separated into two separate days, with at least 48 hours between them, to provide enough time for complete rest and recovery between sessions. Both testing sessions were carried out at the same time of day; 10:00 to 13:00, to prevent the diurnal rhythm fluctuation from affecting the subjects' performance. After the completion of the 8 weeks of training, the exact same testing protocols implemented in the pretraining phase were replicated for the retest phase.

Testing Day 1. The first testing session included the following tests; Kraus-Weber (K-W) test, trunk lift test, 4-level abdominal strength test, 7-stage abdominal strength test, double leg-lowering test (DLLT), two separate sit-up tests; 30 and 60seconds, Sorensen test, ito test, prone double straight-leg raise test, arch-up test and isometric trunk endurance test (prone plank). At least four minutes of rest were allowed following a test that required maximal effort to promote full recovery before proceeding with the next test. The Kraus-Weber (K-W) test evaluates the flexibility and strength of the major core muscles involved in posture¹⁸. The trunk lift test can reliably measure the strength and flexibility of the trunk extensor muscles¹⁹. Three trials were allowed for each participant, with the best score being recorded. A maximum score

of 30cm was set to prevent hyperextension of the spine and avoid compression of the intervertebral discs. The 4-level abdominal strength test evaluates abdominal and lower back muscle strength, which is essential for core stability²⁰. Participants were allowed a few trials at each level to familiarise themselves with the test requirements. The 7-stage abdominal strength test evaluates abdominal strength, which is essential for core stability and back support²¹. Participants were allowed a few tries at each stage to allow for familiarization with the stage requirements. The Double leg-lowering test calculates the extent of an individual's abdominal muscle strength, which is very important, as poor abdominal muscle strength can lead to bad posture and, subsequently, the onset of LBP²². The scoring involved the lowest angle to which an individual could lower the legs before the contraction of the abdominals was released. To measure the angles from the floor to the participant's legs, the Guymon Goniometer (Model 01129, Lafayette Instrument, LAFAYETTE, IN, USA) was selected as it has repeatability and accuracy of $\pm 1^{\circ}$ ²³. Two trials were allowed for each participant. The average of the two trials was calculated for the final result of the test. The sit-up test is widely implemented to measure the muscular endurance of the hip flexors and abdominal muscles, which is pivotal in rehabilitating and preventing disorders associated with LBP²⁴. The scoring criterion was the number of sit-ups. A complete sit-up count was valid only if the upper back was in contact with the floor. Pausing to rest was only permitted in the up position. Some protocols suggest that the participants' feet should be held on the ground to make it easier for them to perform in a more controlled manner. However, this was not implemented in this study because securing the feet decreases the validity of the test due to an increased involvement of the hip flexors²⁵. Two separately timed sit-up tests were performed; one at 30sec and one at 60sec. The Sorensen test could be described as the most commonly implemented and researched test regarding trunk extensor muscle strength and endurance²⁶. Although most researchers use this test to measure strength, it primarily evaluates the static endurance of the muscles²⁷. For the Ito test the participants would lie in a prone position, with a small pillow placed under the lower abdomen and the hands held to the sides of the body²⁸. Then, the upper body would be lifted off the floor, and they would try to hold it up for as long as possible. The test was terminated whenever the participant could not keep the chest off the floor for more than five seconds. The maximum time allowed for the test was four minutes. The prone double straight-leg raise test aims to assess the isometric endurance of the extensors of the lower back²⁹. The test was terminated whenever the subject could not keep their knees off the floor for more than five seconds. The maximum time allowed for the test was four minutes. The arch-up test is often compared to the Sorensen test and is reviewed as a dynamic variation. It measures the muscular endurance of

the extensors of the trunk³⁰. For the execution of this test, the participants assumed the prone position on the Roman chair. The superior end of the pelvis was aligned with the edge of the chair, and the arms were crossed on the chest. Then, the tester would place the palm on the participant's scapula to prevent hyperextension of the trunk. Next, the participants would flex the trunk to a previously specified position of 30° degrees of flexion and then return up towards the tester's palm for as many repetitions as possible³¹. Repetitions had to be performed in a slow and controlled manner; 2-3 seconds per repetition. The prone plank exercise was implemented as a testing procedure, as it can reliably and validly measure the isometric endurance of the global core muscles in athletes³². A standard prone plank position was used for the test; particular attention was given to the positioning of the pelvis, which had to remain in a neutral position. The test was terminated whenever a participant could not keep the body in a straight line parallel to the floor for more than five seconds. The maximum time allowed for the test was four minutes.

Testing Day 2. For the second testing session, measurements from the abdominal test and evaluation systems tool (ABTEST) and the trunk's isokinetic flexion and extension were taken. The ABTEST is an isometric test used to measure abdominal muscle strength. Each participant was allowed three submaximal trials for familiarization, followed by two maximal trials. Since this test measures maximal effort, at least four minutes of rest were provided between each maximal trial. Additionally, participants were instructed to inhale normally and exhale slowly throughout the ten-second trials to avoid the Valsalva maneuver. This test recorded maximal and minimal effort in kilograms (kg). Furthermore, the fatigue index (FI) was calculated and represented the percentage overall decrease in force. The Humac Norm Testing and Rehabilitation system, Isokinetic Dynamometer (Model 770, CSMi Medical & Solution, USA), was used to measure the isokinetic muscle function of the trunk. First, four sub-maximal repetitions of concentric trunk flexion and extension were performed at both angle speeds of 60°·sec⁻¹ and 180°·sec⁻¹ for familiarization with the test and the speeds. Then, for the testing phase, four maximal repetitions were performed at angle speeds of 60°·sec⁻¹ and 180°·sec⁻¹. With this isokinetic assessment, trunk muscle function was evaluated by measuring peak torque, work per repetition and average power per repetition for both the flexors and the extensors at both speeds. Table II below lists all the tests of both testing sessions.

** Place Table II here **

Training Regime. All training sessions were initiated with the warm-up phase, which followed the same protocol used during the testing sessions. According to Akuthota and Nadler³³, all core strengthening and stability training programs should begin with the

participants recognizing the neutral position of the spine. Following that acknowledgement, the main training session was commenced which consisted of ten exercises, listed in Table III. The first three exercises were termed by McGill as the "big three" and are considered essential for core fitness³⁴. Moreover, beginners can safely execute them, and modified versions are available for more advanced individuals³⁴. According to Lehman³⁵, the side bridge, prone plank, curl up, and bird dog exercises challenge the muscles and build muscle endurance. The three variations of the pelvic bridge exercise were replicated from a study that looked at firefighters and core strength concerning injury prevention¹¹. The first exercise is the traditional pelvic bridge on the floor, while the other two variations implement a Swiss ball. Using a Swiss ball favours core stability through increased activation of the core musculature compared to performing the same exercises on a conventional stable surface³⁶. Furthermore, electromyography findings have revealed that the external and internal obliques are the primary muscles involved in axial rotational movements of the trunk³⁷. Thus, the standing oblique twist exercise aims to strengthen the oblique muscles to prevent the onset and progression of LBP. Finally, the Superman exercise targeted the erector spinae muscles and was demonstrated as safe and effective in rehabilitating patients with LBP³⁸. All participants were advised to have their last meal at least two hours before each training session. Furthermore, a consistent and regular respiratory rate was advocated for all exercises and was consistently emphasized throughout the training sessions.

** Place Table III here **

Statistical Analysis

SPSS 26.0 for Macintosh (SPSS Inc., Chicago, IL, USA) was used for the statistical analysis. The normality and homogeneity of the variances were assessed using the Shapiro-Wilk and the Brown and Forsythe tests, respectively. The descriptive statistics were calculated as means and standard deviations. Normally distributed variables were analyzed with the paired samples t-test, while non-parametric variables were analyzed with the Wilcoxon signed-rank test. The level of p -value significance was set at $p \leq 0.05$.

RESULTS

Statistical analysis revealed significant differences for the 30sec sit-up test; $t(12) = -2.39$, $p < 0.05$ and the double leg-lowering test; $Z = -1.98$, $p < 0.05$, which was also the only variable with significant differences among the non-parametric, as shown in Table IV. The ABTEST measurements were all significantly different, except for the fatigue index, as shown in Table V. The t-test results were as follows: maximum effort; $t(15) = -3.13$, $p < 0.05$,

minimum effort; $t(15) = -3.60, p < 0.05$, power index; $t(15) = -3.52, p < 0.05$ and abdominal strength index; $t(15) = -3.28, p < 0.05$. Finally, among the isokinetic trunk flexion-extension measurements, two variables were found to have significant differences between pre-training and post-training; peak torque of the extensors at $180^\circ \cdot \text{sec}^{-1}$; $t(6) = -3.10, p < 0.05$ and the angle of the trunk at which the extensors reached peak torque at $60^\circ \cdot \text{sec}^{-1}$; $t(15) = -2.24, p < 0.05$, as shown in Table VI.

**** Place Table IV here ****

**** Place Table V here ****

**** Place Table VI here ****

DISCUSSION

This study examined the effectiveness of an eight-week training regime on core strength, muscular endurance, and low back pain reduction in police and firefighter personnel. Despite the experimental design's brief timeframe, the results substantiate the program's effectiveness in numerous fitness areas, underscoring its potential for delivering promising outcomes.

Notably, the results indicated that the performance on the ABTEST device improved significantly following the exercise regime. Specifically, all the ABTEST variables had improved compared to the baseline, except for the fatigue index. Failure to indicate improvements in muscular endurance with the ABTEST device could be that the fatigue index is calculated based on the reduction in isometric force within only a 10-second period. Thus, the 10-second timeframe might have been too short for muscular fatigue to occur. However, significant improvements in abdominal muscular endurance were indicative in other tests, specifically the 30-second sit-up and double leg-lowering tests. The sit-up test is commonly utilized in physical examinations for police officers and firefighters during the induction process³⁹. Typically, the 60-second sit-up test is widely accepted, as evidenced by existing literature. For instance, Sharkey et al.⁴⁰ measured that 638 firefighters were able to perform an average of 25.40 ± 5.10 sit-ups in one minute, while Michaelides et al.⁴¹ reported that 38 firefighters achieved 36.00 ± 18.06 sit-ups within the same time frame. In the case of police officers, Kukic et al.⁴² found that 163 male police officers completed an average of 41.19 ± 11.05 sit-ups in two minutes. When comparing the results of the current study's minute-long sit-up test (pre-training: 29.38 ± 9.74 ; post-training: 31.73 ± 9.07) with the findings of Sharkey et al.⁴⁰ and Michaelides et al.⁴¹, there is no significant disparity between the numbers.

Interestingly, this study identified a notable research gap in the domain of physical fitness assessment within the contexts of police and firefighter professions, particularly

concerning the 30-second sit-up. These results indicate the program's effectiveness on the abdominal muscles, since the ABTEST can validly measure abdominal strength by limiting the involvement of the hip flexor muscles⁴³. What is more, Michaelides et al.⁴⁴ compared the ABTEST measurements on firefighters' ability tests, incorporating six tasks that simulated firefighting tasks. The authors found that firefighters who performed better at said ability test also had greater abdominal strength than firefighters with weaker performance on the ability test.

Furthermore, the analysis of the isokinetic evaluation of trunk muscles demonstrated significant differences in peak torque measurements of the trunk extensor muscles at $180^{\circ}\cdot\text{sec}^{-1}$, and the trunk's angle at which the extensor muscles' peak torque at $60^{\circ}\cdot\text{sec}^{-1}$ was reached (see Table VI). To our knowledge, no studies have assessed trunk flexion-extension at an angular velocity of $180^{\circ}\cdot\text{sec}^{-1}$. However, the isokinetic trunk flexion and extension at $60^{\circ}\cdot\text{sec}^{-1}$ in untrained individuals were recorded by Thompson et al.⁴⁵, and peak moment torque values were 248.93Nm and 259.64Nm for flexion and extension, respectively. The current investigation recorded higher values than Thompson et al.⁴⁵. Particularly the peak torque of flexors for pre-training was 255.75Nm, while for post-training, it was 262.75Nm, and the peak torque for extensors was 277.31Nm and 283.25Nm for pre-training and post-training, respectively. This difference in values between Thompson et al.⁴⁵ and participants in this study could be attributed to the higher fitness level that police officers and firefighters possess due to the nature and requirements of their work. As for the angle of the trunk at peak torque of the flexor muscles at $60^{\circ}\cdot\text{sec}^{-1}$, Thompson et al.⁴⁵ measured it at 46.8° , which is greater than in this research; 30.44° for pre-training and 35.44° for post-training. In contrast, values of the angle of the trunk at peak torque in extension at $60^{\circ}\cdot\text{sec}^{-1}$ are very similar between the two studies. Thompson et al.⁴⁵ stated that peak moment torque was achieved at 34.6° , while we recorded it at 32.38° for pre-training and 37.19° for post-training, as shown in Table VI.

An inverse relationship exists between movement velocity and force production; while velocity increases, force production decreases and vice versa. Van Damme et al.⁴⁶ investigated this through electromyographic analysis of the activity of local and global muscles of the lower back and abdominal regions during maximal isokinetic trunk flexion and extension at four different angular velocities; $30^{\circ}\cdot\text{sec}^{-1}$, $60^{\circ}\cdot\text{sec}^{-1}$, $90^{\circ}\cdot\text{sec}^{-1}$ and $120^{\circ}\cdot\text{sec}^{-1}$, in Belgian defense employees of both genders. As expected, the authors confirmed that muscle activity in the lower back significantly decreases as velocity increases, since fast contractions require only fast twitch muscle fibre activation versus the slow and more powerful movements that allow for both fast and slow twitch muscle fibre recruitment⁴⁷. These important physiological

revelations regarding trunk muscle activation could highlight the importance of incorporating exercises of varying speeds and resistances when training the core muscles to engage both the deep local stabilizing muscles and the superficial global muscles.

The findings of the isokinetic trunk testing indicate the highest torque and its angle holds significance for instructors specializing in the preparation of emergency personnel. They offer a comprehensive understanding of the biomechanics underpinning the correct lifting of heavy objects, an activity intrinsic to their profession. Furthermore, proficiency in these mechanics is not only critical for injury prevention but also for the strengthening and recuperation of trunk muscles, notably in the context of preventing or recovering from groin injuries, which are prevalent within this professional group⁴⁸. Furthermore, Bergmark⁴⁹ suggested that core strengthening and stability training regimes should include a range of exercises that will challenge the core musculature throughout the whole range of motion and in all three planes of movement due to the differences in muscle activation between each exercise. Based on that, exercises that implement all trunk movements were selected for the 8-week training intervention. Additionally, isometric strength measurements are commonly implemented in LBP rehabilitation programs based on findings that LBP is associated with decreased isometric strength⁵⁰. This is why isometrics were included in both the testing and the intervention of this study. Isometric testing underestimates a considerable amount of the forces that load the spine during dynamic lifting, as the forces are 33-60% lower under static conditions than in dynamic movements⁵¹. Nevertheless, the baseline ODI scores in this study were already relatively low, with only one individual scoring slightly over minimal disability. This left little but promising room for improvement following the training intervention as the ODI scores were slightly reduced. Additionally, small improvements, some of which were significant, were also observed in the performance tests. The small differences were attributed to the fact that the selected population is already very well trained due to the nature of their work. It is also important to acknowledge that this study has additional limitations, including a small sample size and the absence of a control group. Addressing these in future studies will strengthen the generalizability of the findings.

CONCLUSIONS

In conclusion, the results underscore the exercise program's success across various fitness parameters, as evidenced by improvements in the ABTEST device performance, abdominal endurance, and isokinetic evaluation of the trunk muscles. Additionally, the study highlights avenues for further research in refining fitness testing and interventions for high-

risk professionals such as policemen and firefighters that will assist them in addressing the unique challenges faced in these professions by maintaining optimal health and preventing work-related injuries.

The findings of this study yield noticeable future implications that bear significance for fitness professionals, particularly in the context of optimizing core stability among emergency response personnel. Isokinetic training and testing of trunk extension at low speeds is advisable. This recommendation derives from the observed peak torque disparities when speeds surpass angular velocities of $60^{\circ}\cdot\text{sec}^{-1}$. Low speeds allow for both the local and global muscles of the lower back, while faster speeds may yield inconclusive data in the context of core assessments. The isometric training of the abdominal muscle should be prioritized in the fitness regimens of these emergency response personnel. The improvements observed in the ABTEST testing, which predominantly engage the abdominal muscle's isometric contractions, highlight the efficacy of such exercises. In the same context, the results of abdominal testing demonstrate the unique characteristics of abdominal muscular endurance exhibited by the emergency response personnel in comparison to other populations, as evidenced by the 30-second sit-up test and the double leg-lowering test. These results can inform fitness professionals to address the specific needs of these emergency personnel since this emphasis is integral to the requisites of their professional tasks. Fitness professionals specializing in the preparation of emergency personnel should integrate biomechanical insights obtained from the isokinetic trunk measurements into the training programs. These findings offer a better understanding of the biomechanics of lifting heavy objects, a critical skill for these occupations, contributing to injury prevention, rehabilitation and strengthening of the trunk muscles. Finally, with respect to the multifaceted nature of the core musculature, training interventions should also include exercises that challenge the core throughout the various planes of movement and the whole range of motion.

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Notes

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions: All authors read and approved the final version of the manuscript.

Antoniou P. Sotos: study design, data collection, writing, proofreading of the manuscript.

Parpa M. Koulla: data analysis, proof reading of the manuscript.

Michaelides A. Marcos: concept/idea for the study, data collection, data analysis, writing, proofreading of the manuscript.

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TABLES

Table I. Descriptive Statistics for the anthropometric measurements, fitness level and oswestry disability index (data shown as Mean $\pm$ SD).

	Pre-training	Post-training
Age (years)	40.75 $\pm$ 8.51	40.75 $\pm$ 8.51
Height (cm)	177.69 $\pm$ 6.28	177.69 $\pm$ 6.28
Body Mass (kg)	85.50 $\pm$ 10.87	84.88 $\pm$ 10.49
Fitness Level (hours $\cdot$ week ⁻¹)	7.38 $\pm$ 6.38	7.00 $\pm$ 5.93
Oswestry Disability Index (%)	7.00 $\pm$ 7.12	5.75 $\pm$ 4.89

Table II. The test battery to assess core fitness.

Test Name (in order of execution)	Test Evaluation	Unit of Measurement
Kraus – Weber test	flexibility and strength of major core muscles involved in posture	Pass or Fail
Trunk Lift test	strength and flexibility of the trunk extensor muscles	cm
4-Level Abdominal strength test	abdominal and lower back muscle strength	No. 0-16
7-Stage Abdominal strength test	abdominal muscle strength	No. 0-7
Double Leg-lowering test	abdominal muscle strength	Degrees of angle (°)
Sit-Up tests (30 & 60Sec)	muscular endurance of the hip flexors and abdominal muscles	Number of sit-ups performed
Sorensen test	trunk extensor muscle strength and endurance	s
Ito test	isometric endurance of the extensors of the lower back	s
Straight Leg Raise test	isometric endurance of the extensors of the lower back	s
Arch-Up test	muscular endurance of the extensors of the trunk	No. of Repetitions
Plank	isometric endurance of the global core muscles	s
Abdominal Test and Evaluation Systems Tool (ABTEST)	abdominal muscle strength	Kg, % & Watts
Isokinetic Testing	isokinetic muscle function of the trunk	N_m, % & (°)

Table III. Eight-week training intervention.

Exercise	Sets	Reps/ Time	Rest and Recovery	Primary Target Muscles
McGill Curl-up	3	10-12 reps	30-sec rest between each set and 1- minute rest between each exercise	Abdominal endurance, strengthening and toning of rectus abdominis, and external and internal oblique
Side Bridge (aka Side Plank)	3	30 sec (each side)		Transversus abdominis, gluteus medius and gluteus minimus (abductors), the adductor muscles of the hip, and the external and internal obliques
Bird Dog	3	20 reps (10 each side)		Abdominal, lower back, gluteal and thigh muscles
Prone Plank	3	45 sec		Erector spinae, rectus abdominis and transverse abdominis
Pelvic Bridging	3	45 sec		Rectus abdominis, erector spinae, hamstrings and adductors
Leg Raises	3	10-12 reps		Rectus Abdominis
Pelvic Bridging with the upper back placed on a Swiss ball	3	30 sec		Rectus abdominis, erector spinae, hamstrings and adductors
Standing oblique twist with a bar	3	20 reps (10 each side)		External and internal obliques
Pelvic Bridging with the heels of the feet placed on a Swiss ball	3	30 sec		Rectus abdominis, erector spinae, hamstrings and adductors
Superman	3	20 reps (10 each side)		Erector Spinae, gluteal muscles, hamstrings

Table IV. Descriptive Statistics for the tests included in the first testing session of the testing procedure (data shown as Mean $\pm$ SD).

	Pre-training	Post-training
K-W test (1=pass, 2=fail)	1.44 $\pm$ 0.51	1.31 $\pm$ 0.48
Trunk Lift test (cm)	27.19 $\pm$ 3.82	27.88 $\pm$ 3.30
4-Level test (score)	14.88 $\pm$ 2.13	15.13 $\pm$ 2.19
7- Stage test (stages)	5.00 $\pm$ 2.10	5.38 $\pm$ 2.09
Double Leg-lowering test ($^{\circ}$)	24.69 $\pm$ 18.84	17.31 $\pm$ 13.91*
30sec Sit-Up test (rep)	16.23 $\pm$ 2.65	17.40 $\pm$ 4.03*
60sec Sit-Up test (rep)	29.38 $\pm$ 9.74	31.73 $\pm$ 9.07
Sorensen test (sec)	113.06 $\pm$ 49.63	121.20 $\pm$ 53.20
Ito test (sec)	205.38 $\pm$ 67.78	206.27 $\pm$ 54.94
Straight Leg Raise test (sec)	154.06 $\pm$ 80.83	158.53 $\pm$ 73.41
Arch-Up test (rep)	37.06 $\pm$ 14.46	41.13 $\pm$ 19.31
Plank (sec)	154.63 $\pm$ 60.06	155.00 $\pm$ 72.08
* $p < 0.05$		

Table V. Descriptive Statistics for the ABTEST Measurements (data shown as Mean $\pm$ SD).

	Pre-training	Post-training
Maximum effort (kg)	54.38 $\pm$ 9.06	61.50 $\pm$ 9.53**
Minimum effort (kg)	40.81 $\pm$ 7.85	47.94 $\pm$ 5.81**
Fatigue Index (%)	25.31 $\pm$ 7.61	21.88 $\pm$ 5.64
Power Index (watts)	4185.56 $\pm$ 744.48	4818.88 $\pm$ 668.95**
** $p < 0.01$		

Table VI. Measurements of Peak Torque and the Angles of the Trunk when Peak Torque was achieved (data shown as Mean $\pm$ SD).

	Pre-training	Post-training
Peak torque of flexors at $60^{\circ}\cdot\text{sec}^{-1}$ (N_m)	262.75 ± 43.79	255.75 ± 43.88
Peak torque of extensors at $60^{\circ}\cdot\text{sec}^{-1}$ (N_m)	277.31 ± 56.66	283.25 ± 59.44
Torque ratio of flexors-extensors at $60^{\circ}\cdot\text{sec}^{-1}$ (%)	96.69 ± 14.97	92.25 ± 16.09
Peak torque of flexors at $180^{\circ}\cdot\text{sec}^{-1}$ (N_m)	145.69 ± 57.83	154.27 ± 59.32
Peak torque of extensors at $180^{\circ}\cdot\text{sec}^{-1}$ (N_m)	103.44 ± 71.58	$154.88 \pm 70.61^*$
Torque ratio of flexors-extensors at $180^{\circ}\cdot\text{sec}^{-1}$ (%)	314.78 ± 335.47	125.25 ± 48.89
Angle at peak torque of flexors at $60^{\circ}\cdot\text{sec}^{-1}$ ($^{\circ}$)	30.44 ± 14.39	35.44 ± 12.99
Angle at peak torque of extensors at $60^{\circ}\cdot\text{sec}^{-1}$ ($^{\circ}$)	32.38 ± 7.97	$37.19 \pm 5.32^*$
Angle at peak torque of flexors at $180^{\circ}\cdot\text{sec}^{-1}$ ($^{\circ}$)	48.75 ± 1.34	47.94 ± 2.95
Angle at peak torque of extensors at $180^{\circ}\cdot\text{sec}^{-1}$ ($^{\circ}$)	6.13 ± 3.65	6.81 ± 4.28
$*p<0.05$		