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Effect of core stabilization on lumbosacral angle in centrally obese adolescents: A randomized controlled trial

Marian M. Shafeek [a,b], Ahmed S. Ali [c], Hanan Hosny M. Battesha [d,*], Noha Aly Mohamed [e], Ahmed Mahmoud Hamed Hasnin [f], Sami kamal Mohamed Elgendy [e], Ibrahim M. Abdelhakim [a,g]

[a] Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, October University for Modern Sciences & Arts (MSA University), 6th October, Egypt
[b] Department of Physical Therapy for Pediatrics and Its Surgery, Faculty of Physical Therapy, Modern University for Technology and Information, Cairo, Egypt
[c] Department of Basic Science, Faculty of Physical Therapy, Modern University for Technology and Information, Cairo, Egypt
[d] Physical Therapy Department, Faculty of Applied Medical Sciences, Al-Zaytoonah University of Jordan, Amman, Jordan
[e] Department of Physical Therapy for Internal Medicine and Elderly, Faculty of Physical Therapy, Modern University for Technology and Information, Cairo, Egypt
[f] Department of Physical Therapy, Faculty of Applied Medical Sciences, Al-Zaytoonah University of Jordan, Amman, Jordan
[g] Department of Physical Therapy, National Institute for Neuromotor System, Giza, Egypt

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ABSTRACT

Objective: To assess the effects of core stabilization exercises (CSE) on the lumbosacral angle (LSA), low back pain (LBP), and functional disability compared to conventional physical therapy in adolescents who are centrally obese.
Design: Randomized controlled study.
Methods: Forty adolescents with central obesity and chronic LBP were randomly assigned to either an experimental group participating in a structured CSE program or a control group receiving conventional physical therapy. Participants were randomly assigned to either group using concealed allocation through sealed opaque envelopes. Treatment sessions were 45 min, three times weekly for 12 weeks. The primary outcome measure was LSA, and Secondary measurements included the Functional Disability Inventory (FDI) to measure functional disability and the Visual Analog Scale (VAS) to determine the intensity of LBP. Both groups were tested before and after treatment.
Results: Both groups showed significant post-treatment improvements ($p < 0.001$). The experimental group showed greater improvement in LSA and FDI than the control group, with profound and very large effect sizes, respectively. No significant between-group difference was found for VAS, with a negligible effect size.
Conclusion: CSE and conventional therapy effectively manage chronic LBP in centrally obese adolescents, with stabilization programs significantly better at correcting the LSA and reducing disability.

1. Introduction

Obesity and other nutrition-related disorders in children and adolescents are on the rise worldwide, but especially in the Middle East (Al-Qerem et al., 2025). Central obesity is the accumulation of fat around the waist, which influences body balance and posture. (Nahorna and Baur) During adolescence, this can result in postural changes due to an increase in waist circumference, shifting the center of gravity forward (Sharma and Rawat, 2023). This increased pressure on lumbar vertebrae predisposes one to low back pain (LBP) and correlates with increased lordosis, which in turn leads to LBP and disability (Abdel-Aziem and Elzaki, 2022; Lucha-Lopez et al., 2020).

Lumbosacral Angle (LSA) is vital for spinal alignment and for sharing mechanical loads between the lumbar spine and pelvis, affecting posture and movement in adolescents (In et al., 2021). Many methods used to measure this angle, but Ferguson's Angle is the most popular (Betz et al., 2024). This angle, formed between the sacrum's base and the horizontal plane, links closely with lumbar lordosis (Galbusera et al., 2022). According to studies, LSA may be a biomechanical marker for predicting risk factors in LBP (Johnson et al., 2024). Core-stabilization exercises (CSE) focuses on motor control exercises that enhance lumbopelvic stability while reducing the strain on the passive structures of the spinal column (Skundric et al., 2021), it involves the activation of local core stabilizing muscles-transversus abdominis, multifidus, internal oblique,

* Corresponding author. Physical Therapy Department, Faculty of Applied Medical Sciences, Al-Zaytoonah University of Jordan, Jordan.
E-mail address: h.hosny@zuj.edu.jo (H.H.M. Battesha).

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thoracolumbar fascia, and pelvic floor muscles-in order to attain lumbar-pelvic stability before distal movements are initiated (Dyer, 2014).

Previous studies showed that CSE enhance spinal posture by increasing muscle strength that stabilizes lumbar spine alignment (Skundric et al., 2021); however, its effect on LSA in obese adolescents is unclear due to a lack of randomized control trials that compare CSE directly to conventional physical therapy in centrally obese adolescents. Excess weight in centrally obese adolescents alters the biomechanics of the spine and leads to postural deviations. Knowledge about the effect of core stabilization on LSA could be applied to create preventive measures and rehabilitation programs for this population. Therefore, this randomized controlled trial aimed to examine the specific effects of a structured CSEs program on the LSA, LBP, and functional disability compared with conventional physical therapy in centrally obese adolescents.

2. Methods

2.1. Research design and ethical considerations

This study used a randomized control trial design, approved by the Research Ethics Committee of the Faculty of Physical Therapy, MTI University, Egypt (REC/2111/MTI.PT/2504291). The trial was registered in the Pan African Clinical Trials Registry (PACTR, 202506654427755). Participants were fully informed about the nature of the study and gave written informed consent to participate in it, so their rights were protected. The study's procedures were conducted at the outpatient physical therapy clinic, MTI University.

2.2. Sample size calculation

The sample size was determined using G*Power 3.1.9.4 for an independent-samples *t*-test (two-tailed, $\alpha = 0.05$, power $= 0.80$). With a conservative d $= 1.0$ based on effect sizes derived from a prior study of lumbar lordosis reduction (Shalamzari et al., 2024), the sample size was set at 20 participants per group to ensure strength and account for possible attrition, totaling 40 participants.

2.3. Participant selection

Forty adolescents aged 13 to 18 years were chosen for the study from forty-eight obese patients referred by an orthopedist. They had chronic LBP lasting over three months and met criteria, including a BMI >95th percentile and waist circumference ≥90th percentile based on age and sex (Sayed, 2016). Exclusion criteria included prior spinal surgery, neurologic disorders, other musculoskeletal disorders, and ongoing physical therapy. Volunteers were randomly assigned to the experimental group for CSE or the control group using concealed sequences in sealed envelopes (Fig. 1).

2.3.1. Assessment methods

The primary outcome measure was LSA, while the secondary measures were LBP intensity and functional disability. All measures were collected before and after the 12-week intervention period for all participants. A blinded assessment was conducted by all outcome evaluators, minimizing detection bias and improving the reliability of comparing outcomes between obese adolescents in the CSE and control groups.

The LSA assessment involved measuring Ferguson's Angle, a recognized measure (Wahab et al., 2024). The angle was measured from a

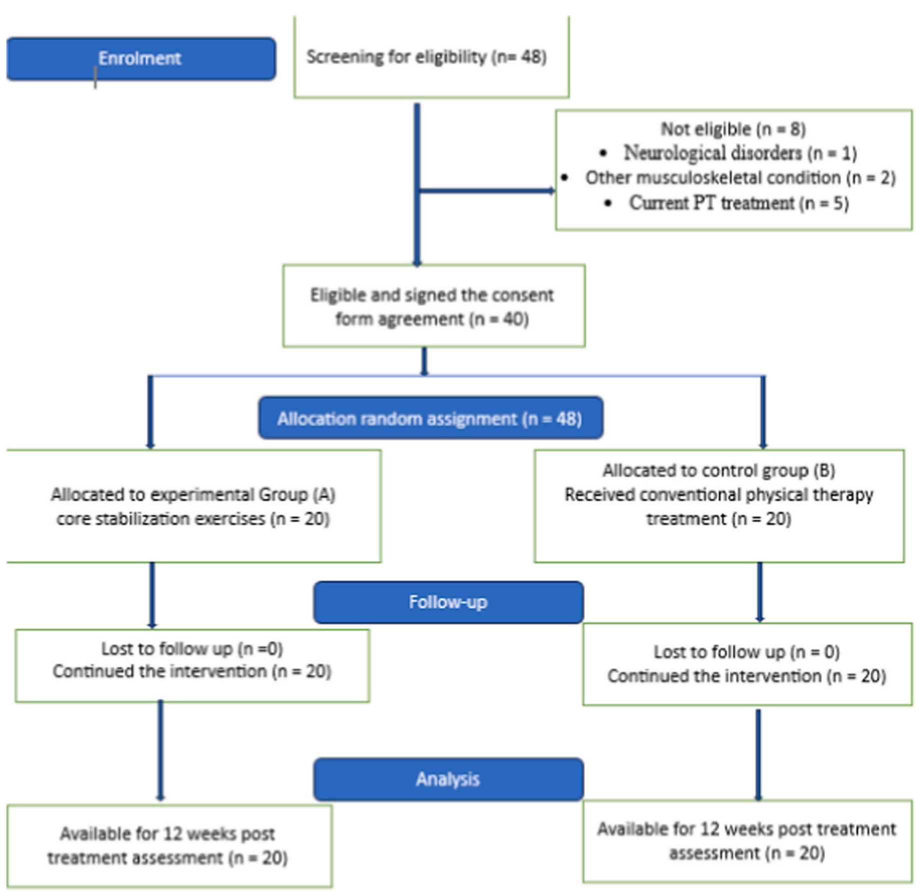

Fig. 1. A flow chart of patients' recruitment and retention throughout the study.

standing lateral lumbosacral radiograph including the superior endplate of S1 and femoral heads. Radiographs were available in DICOM format and were imported for analysis using Surgimap Spine software (version 2.3.2) (Fig. 2). This program provides precise and valid measurements, making accurate and proper communication crucial for clinical research (Betz et al., 2024; Maillot et al., 2015). All participants presented with increased LSA values at baseline, consistent with the altered spinopelvic alignment commonly reported in adolescents with central obesity. All radiographic measurements were performed by the same blinded assessor to minimize measurement variability.

2.3.2. Secondary outcomes

1 The severity of LBP was measured by Visual Analog Scale (VAS), a 10-cm line that measures pain, (0 = no pain, 10 = worst pain). Patients mark their level of discomfort. This tool is reliable and valid (Åström et al., 2023).
2 Functional disabilities were measured using the Functional Disability Inventory (FDI), a measure of the difficulty in performing various tasks, which is scored on 15 items on a 0–4 scale based on recent history. The total score ranges between 0, which reflects no disability, and 60, reflecting severe disability, and is divided into scores indicating mild (0–12), moderate (13–29), and severe (30 or more) disability. The FDI is a valid and reliable measure and has been used in the research of children and adolescents with chronic pain (Ghomian et al., 2022; Madi and Clinton, 2015).

2.3.3. Intervention protocol

The experimental group engaged in a structured CSE program designed to reduce excessive curvature in the lumbar spine, strengthen underdeveloped core and gluteal muscles, stretch tight hip flexors and lumbar extensors, and improve postural awareness and dynamic balance. The intervention consisted of a 12-week CSE program performed 3 times per week, with each session lasting approximately 45 min. Exercise progression was individualized according to each participant's tolerance. Progression was achieved by gradually increasing holding time, repetitions, and exercise complexity while maintaining proper technique and symptom-free performance. Both groups received identical warm-up and cool-down protocols to ensure standardization of the intervention, while the differences between groups were limited to the main treatment program only.

The warm-up and cooling down consisted of static/dynamic stretching and mobility exercises such as supine pelvic tilt, standing pelvic tilt, Cat-Cow Stretch, and Child's Pose. At the end of the session, there was a 5-min cool-down period that allowed participants to carry out gentle static stretches targeting the major muscle groups used during the workout.

The main exercise phase includes different types of exercises as core strengthening exercises, Abdominal Prone Extensor Strengthening, Anti-Rotation Training, Anti-Extension Training, Stretching and Postural and Functional Training (Table 1).

The session typically concluded with a cool down of 5-10 min consisting of deep breathing and supine hamstring stretching with foam rolling (Shalamzari et al., 2024; Javadipour et al., 2021).

The control group received conventional physical therapy by a course of Williams flexion exercises (Fatemi et al., 2015), aims to reduce lumbar lordosis and strengthen abdominal muscles with no CSE. The program lasted 12 weeks and included training sessions for 45 min held three times a week. It began with a 5-min warm-up in the form of light aerobic activities such as stationary cycling or brisk walking to prepare their bodies. Followed by 35 min of the prescribed exercises in sequence. The exercise routine featured a total of seven exercises (Table 2), performed in a specific sequence. Participants were instructed to do two sets of ten repetitions for every exercise unless stated otherwise.

Intervention procedures for both groups were supervised by certified physical therapists with more than five years of experience. All participants completed the intervention, with full adherence and no dropouts, which supports the reliability of the findings. All exercise sessions for both groups were conducted in a clinical setting under the direct supervision of certified physical therapists with more than five years of

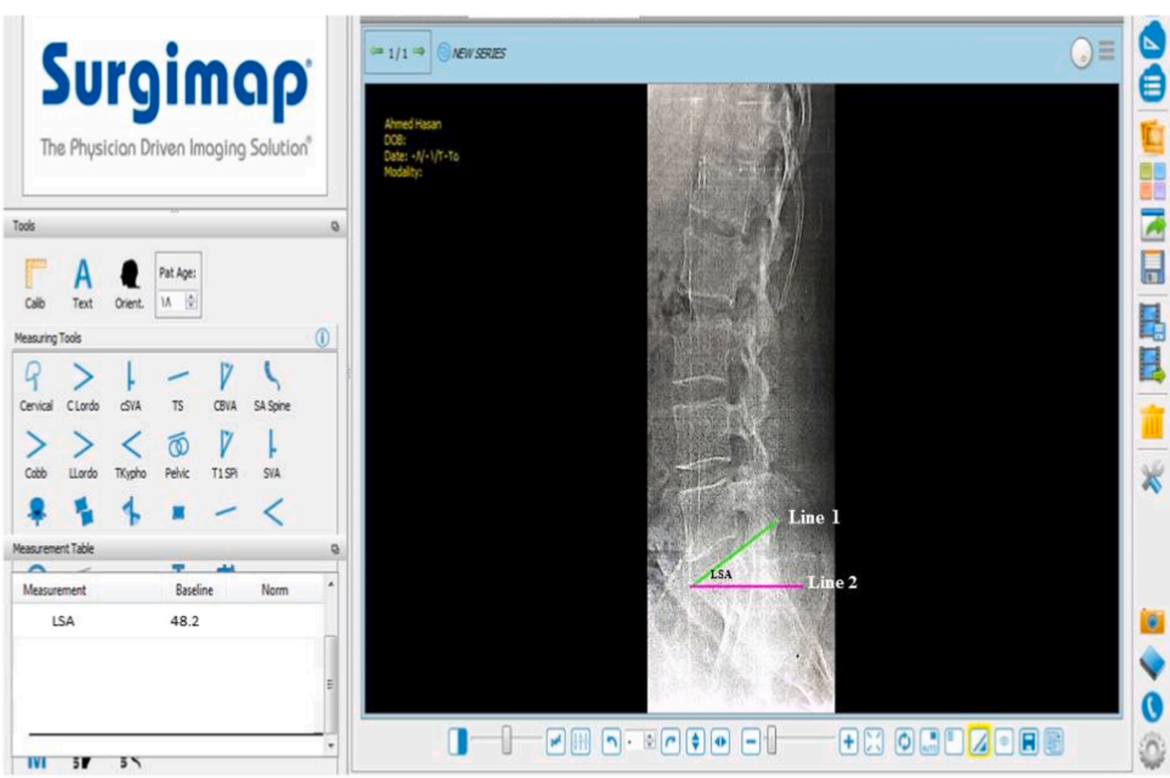

Figure (2). analysis of lumbosacral angle (LSA).

Table (1)
The main exercises phase for experimental group included 3 sets of 10 to 12 repetitions for the following exercises.

Exercise	Description
Abdominal Draw-In Maneuver	Child in crock lying position and ask him or her to Breathe out then gently draw the belly toward the spine without holding breath to improve spine stability and strength abdominal muscles.
Dead Bug	Child supine with 90° flexion of hips and knees then raise one arm over head with extend the opposite knee to improve spine stability and limbs coordination
Plank	Child prone on hands position in a push-up position and maintain all body in straight line to improve posture and alignment
Side Plank	Child side lying position, both legs together, elbow is directly below shoulder and support body weight on the forearm, hold 5- 10 s to improve core stability.
Bird Dog	Child in quadruped position and extend one arm forward while extending the opposite leg backward to enhance core stability and balance.
Glute Bridge	Child in crock lying position then raise both hips and glutes off the ground while knees bent and feet flat on the floor while lying on one's back. For five to 10 s, maintain this posture to improve overall core stability and pelvic alignment
Clamshell	Child on side lying with hips and shoulders stacked to mat with 90° flexion of both knees, keep feet together and gently raised the top knee toward the ceiling to improve mobility
Prone Press-Up	Child prone on hand position then gently press upper body up while keeping hips on the floor to enhance lumbar flexibility.
Superman	Child prone lying position with arms extended overhead. Lift one arm and the opposite leg slightly off the floor to improve lumbar stability.
Arch with Chin Tuck	Child in sitting position then gently arch upper back and move shoulders backward and glide head straight posteriorly to correct posture and relieve pain
Anti-Rotation Cable Press	Child stand Grab the pulley system robs with both hands and pull it to the middle of the chest to protect spine
Standing Oblique Cable Twist	Child stand and grab pulley system rob then rotate trunk to right side then to left side to improve lumbar mobility
Side-Lying Against the Wall	Child side lying position against wall and abduct leg with extended knee toward celling to enhance stability of pelvis
Quadruped Arm/Leg Raise	Child on hands and knees position with extend one arm and the opposite leg simultaneously, hold for 3–5 s to improve lumber stability.
Hip Flexor Stretch	Child half- kneeling position and make full flexion of hip and knee toward chest while maintain other leg lowering from the bed with holds of 20-30 s to enhance lumbar mobility.
Hamstring Stretch	Child Sit or stand or supine and try to reach toward toes while keeping back and knee straight, holds of 20-30 s, to increase hamstring flexibility and improve pelvic alignment
Supine Figure Four Stretch	Child in crock lying position and put one ankle on the opposite knee then pull legs toward chest to relive tightness and pain
Wall Angels	Child stand against wall with both arms in 90° flexion of elbow then slowly slide both arms upward to reach the ceiling, then bring them back down to the starting position to correct posture and relive pain.
Squat with Abdominal Draw-In Maneuver	Child stand against wall with feet hip-width apart and lowering the body down with flexion hip and knee with contact abdominal muscles to improve ankle strategies and pelvic mobility. Proper transversus abdominis muscle activation was taught using standardized verbal instructions and tactile feedback provided by the supervising physiotherapists. Participants were required to demonstrate correct performance before progressing to the exercise program.
Single-Leg Stand with Eyes Closed	Child stand on one leg on hard surface then on foam surface with closed eyes to improve proprioception

Table (2)
The main seven exercises routine for control group.

Exercise	Description
Pelvic tilt	Lying on the back, knees bent, activate the core, and flatten the back for 5-10 s
Single Knee to Chest	From the same position, bring the right knee to the shoulder for 5-10 s, and return. Repeat with the left
Double Knee to Chest	Bring both knees up to chest, hold 5-10 s, and lower one at a time.
Partial Sit-Up	In pelvic tilt, curl head and shoulders up off the floor, and hold momentarily before going back down.
Hamstring Stretch	Sit with legs straight, and lean forward with knees straight
Hip Flexor Stretch	Stand with one foot forward; bend the front knee and lean forward, then switch legs.
Squat	Stand shoulder-width apart, and lower the body by bending knees.

clinical experience. No home-based or unsupervised exercise program was prescribed during the intervention period.

2.4. Statistical analysis

Data were analyzed using IBM SPSS 18 Statistics (IBM Corp., Armonk, NY, USA). Shapiro-Wilk tests confirmed the normality of continuous variables, while paired t-tests evaluated pre- and post-intervention changes in experimental and control groups. Independent t-tests assessed differences between groups at pre-test and post-test stages. Chi-square tests were used to analyze the distributions by gender. Mean differences, percentages, and descriptive statistics were computed. Because the study outcomes (LSA, FDI, and VAS) were pre-defined as primary endpoints rather than exploratory analyses, no formal adjustment for multiple comparisons was applied. Statistical significance was assessed at a two-sided $p < 0.05$.

3. Results

Demographic data results at baseline are shown in (Table 3). There were no statistically significant differences between the two groups for age, weight, height, BMI, waist measurement, or gender distribution ($p > 0.05$). Since demographic data at baseline was evenly distributed across both groups, this helped to reduce confounding bias from demographic factors.

Pre-intervention scores for the Pre-LSA, Pre-VAS, and Pre-FDI showed no significant differences between groups ($p > 0.05$), confirming homogeneity at baseline (Table 4). details independent-samples t-tests comparing groups both pre- and post-intervention. At post-intervention, the experimental group had a greater reduction in LSA compared to controls when compared to baseline testing (mean difference MD $= -4.64 \pm 0.50$, $p < 0.001$), showing improved alignment. Greater functional status improvement was also identified in the experimental group with lower overall Post-FDI scores (MD $= -1.85 \pm 0.50$, $p = 0.001$). While both groups demonstrated decreased pain intensity, no significant change occurred between groups (MD $= -0.10 \pm 0.24$, $p = 0.682$). Overall, both groups benefited from the interventions; however, greater improvements in alignment and functional status were highly evident in the experimental group.

(Table 5) presents within-group comparisons of pre- and post-intervention values for each outcome measure. Experimental group: in the LSA, the value significantly decreased from pre-to post-intervention (MD $= 5.58 \pm 0.43$; 95% CI = 4.68 to 6.48). In the control group, this reduction was also significant (MD $= 1.03 \pm 0.10$; 95% CI = 0.82 to 1.24). The FDI improved in both groups, which means a decrease in the experimental group (MD $= 11.20 \pm 0.50$; 95% CI = 10.16 to 12.24) and in the control group with a mean difference of 9.35 ± 0.45 (95% CI = 8.41 to 10.29). There was a significant reduction in pain intensity in both groups, with the experimental group showing a mean difference of

Table 3
Baseline demographic characteristics of participants in both groups.

Variable	Experimental (n = 20) (Mean ± SD)	Control (n = 20) (Mean ± SD)	Test Statistics	Mean Difference ± SE	95% CI	*p*-value[b]
Age	15.65 ± 1.35	15.80 ± 1.24	−0.367	−0.15 ± 0.41	−0.98 to 0.68	0.716
Weight (kg)	86.16 ± 4.75	87.36 ± 3.37	−0.92	−1.20 ± 1.30	−3.83 to 1.44	0.365
Height (cm)	163.50 ± 5.19	164.40 ± 4.81	−0.57	−0.90 ± 1.58	−4.10 to 2.30	0.573
BMI (kg/m^2)	32.23 ± 1.06	32.33 ± 1.00	−0.34	−0.11 ± 0.33	−0.77 to 0.55	0.737
WC (cm)	98.55 ± 1.89	98.60 ± 1.97	−0.07	−0.05 ± 0.61	−1.28 to 1.19	0.942
Gender distribution across both groups						
Male	11 (55.0%)	12 (60.0%)				
Female	9 (45.0%)	8 (40.0%)	***p*-value** [c] 1			

Abbreviations: BMI, body mass index; CI, confidence interval; N, number; SD, standard deviation; SE, standard error; WC, waist circumference.
a Independent-samples t-tests were used for between-group comparisons of continuous variables.
[b]Chi-square test was used for comparison of gender distribution between groups.
[c]p-value <0.05 was considered statistically significant.

Table 4
Between-group comparison of primary outcomes at pre- and post-intervention.

Variable	Mean Difference (Study-Control) ± SE[a]	95% CI	*p* value[b]	*Cohen's d*	*Effect Magnitude*
Pre-LSA (score)	−0.09 ± 0.31 [c]	−0.71 to 0.53	0.772		
Post-LSA (score)	−4.64 ± 0.50 [c]	−5.66 to −3.62	<0.001 ***	−3.00	Profound
Pre-FDI (score)	0.00 ± 0.57	−1.16 to 1.16	1		
Post-FDI (score)	−1.85 ± 0.50 [c]	−2.85 to −0.85	0.001 **	−1.21	Very Large
Pre-VAS (score)	0.00 ± 0.30	−0.60 to 0.60	1		
Post-VAS (score)	−0.10 ± 0.24 [c]	−0.59 to 0.39	0.682	−0.13	Negligible

Abbreviations: CI, confidence interval; FDI, Functional Disability Index; LSA, lumbosacral angle; SE, standard error; VAS, Visual Analog Scale.
**p < 0.01; ***p < 0.001.
d p-value <0.05 was considered statistically significant.
[a] Independent-samples t-tests were used for between-group comparisons.
[b] Cohen's d was calculated as the standardized mean difference between groups.
[c] Negative mean differences and negative Cohen's d values indicate lower scores in the experimental group compared with the control group.

3.70 ± 0.23 (95% CI = 3.22 to 4.18) and the control group a mean difference of 3.60 ± 0.23 (95% CI = 3.11 to 4.09). All of these comparisons showed improvements that were statistically significant ($p < 0.001$).

4. Discussion

Although the lumbosacral angle was designated as the primary outcome because of its biomechanical relevance, the current evidence does not conclusively demonstrate that correction of LSA directly translates into improvements in pain or functional disability. Therefore, the observed changes in LSA should be interpreted in conjunction with patient-centered outcomes rather than as an independent indicator of clinical improvement.

The study results indicate that the CSE program produced significantly greater corrections in the LSA and reductions in functional disability compared to conventional physical therapy, despite both interventions yielding similar and significant reductions in pain intensity.

Previous research emphasized core muscle dysfunction as a cause and perpetuating factor in LBP (Frizziero et al., 2021); they also reported delayed activation of the transversus abdominis as a normal pattern in individuals with LBP and formed the foundation for stabilization therapy intervention. Likewise, others reported CSE to reduce pain and improve function in patients with chronic LBP (Xu et al., 2021). The significant reduction in LSA noted in the experimental group suggests that CSE contribute to the normalization of spinal curvature, which could diminish excessive lumbar spine mechanical loading. This is in agreement with previous research findings that greater core muscle function is associated with better spinal posture and stability (Skundric et al., 2021). Increased lumbar lordosis is associated with altered spinal loading and pain (Yilgor et al., 2017), and thus our findings advance this understanding by demonstrating that CSE are effective in reducing hyper-lordosis in adolescents, a cohort previously underrepresented in most previous studies.

Central obesity in adolescents shifts their center of gravity, increasing the risk of various health issues. This shift moves the center of gravity forward and above the typical level, weakening deep stabilizing muscles and causing hyperactivity in the lumbar erector spinae and iliopsoas, which promotes excessive lumbar lordosis. In standing, these muscles generate forces that lead to compressive lumbar disc loading and microtrauma to the annulus fibrosus, potentially resulting in back pain due to mechanosensitive nociceptors near the lumbar vertebrae. Dysfunctional spinal loading alters the length-tension relationship of spinal muscles essential for sacroiliac joint stability. This dysfunctional state leads to microtrauma, vertebral subluxations, and inhibits proper spinal recovery, worsening back pain (Alice et al., 2022; Patel et al., 2026).

CSE represents a widely used physical therapy approach to manage low-back disorders, aiming to enhance lumbopelvic alignment and activate core musculature effectively (Dyer, 2014). Core muscles—primarily the transverse abdominis, multifidus, pelvic floor muscles, and diaphragm—act as a corset to stabilize the spine through a neutral posture maintained by an optimal lumbosacral angle. The CSE program applied in the current study allows for activation of such muscles in a preplanned and controlled manner, thereby increasing the coordination, strength, and endurance of local and global core muscles and also proprioception (Koumantakis et al., 2021). Lumbosacral alignment influences lumbopelvic-hip rhythm during weight-bearing activities such as walking, running, and standing. From a physical therapy perspective, lumbosacral alignment disturbances are an appropriate rehabilitation plan for the obese adolescent patients with unfavorable postural parameters, either to decrease lumbar-related

Table 5
Within-group changes in primary outcomes from pre-to post-intervention.

Outcome Measure	Mean Difference ± SE[a]	95% CI	*p*-value [b]	Cohen's dz	Effect Magnitude
Experimental Group: Pre-LSA vs Post-LSA	5.58 ± 0.43	4.68 to 6.48	<0.001 ***	2.92	Profound
Control Group: Pre-LSA vs Post-LSA	1.03 ± 0.10	0.82 to 1.24	<0.001 ***	2.29	Very Large
Experimental Group: Pre-FDI vs Post-FDI	11.20 ± 0.50	10.16 to 12.24	<0.001 ***	5.06	Profound
Control Group: Pre-FDI vs Post-FDI	9.35 ± 0.45	8.41 to 10.29	<0.001 ***	4.66	Profound
Experimental Group: Pre-VAS vs Post-VAS	3.70 ± 0.23	3.22 to 4.18	<0.001 ***	3.59	Profound
Control Group: Pre-VAS vs Post-VAS	3.60 ± 0.23	3.11 to 4.09	<0.001 ***	3.44	Profound

Abbreviations: CI, confidence interval; FDI, Functional Disability Index; LSA, lumbosacral angle; SE, standard error; VAS, Visual Analog Scale.
***$p < 0.001$.
c p-value <0.05 was considered statistically significant.
[a] Paired-samples t-tests were used for within-group pre-to post-intervention comparisons.
[b] Cohen's dz was calculated as the standardized effect size for paired comparisons.

pathology or to prevent risk factors.

Central obesity influences lumbosacral alignment by increasing the lumbosacral angle (LSA), an angular relationship delineated by the superior endplate of the sacrum and the posterior vertebral walls of L5–S1 (Qi et al., 2024). The core musculature maintains lumbopelvic stability during daily activities, and central obesity compromises these muscles' capacity to adhere to the transverse abdominis mechanism, diminishing their stabilizing effectiveness (Lusk, 2021). CSE help restore lumbopelvic stability and reduce the excessive increase in the lumbosacral angle associated with central obesity (Shalamzari et al., 2024).

In cases of central obesity, an increased LSA, indicative of hyperlordosis, is linked to more severe LBP. We have shown that strategies for core stabilization can significantly decrease this hyperlordosis. Core stabilization strategies decrease pain through improvements in postural stability, reducing lumbar movement and closing the disparity in muscle strength, endurance, and activation that exacerbates pain. Core muscle hypertrophy reduces segmental lumbopelvic angles and obesity-related LBP (Koumantakis et al., 2021).

The FDI was utilized to assess aspects of day-to-day functioning, including routines, physical function, and self-care activities among adolescents (Hurtubise et al., 2023). A significant improvement in daily functioning after CSE suggests that enhanced muscular control may be beneficial in more effective management of physical activity and reduction of pain due to altered LSA among centrally obese adolescents. The subjects who were subjected to CSE showed appreciable improvements in their disability score compared to the subjects who were subjected to conventional exercise methods. The results were associated with the role of core stability in functional disability prevention and physical performance improvement. Strengthening the core muscles may improve balance, coordination, and stability, leading to enhanced postural control during functional tasks and increased independence in performing daily activities. Core stability may play a protective role by decreasing the prevalence of functional disability and enhancing physical performance in centrally obese adolescents (Ho et al., 2018).

The conventional physical therapy treatment with William's flexion exercises was seen to significantly decrease the LSA in centrally obese adolescents and decrease chronic LBP. This is probably because of increased flexibility of dominant muscle groups, i.e., the hamstrings, hip flexors, and lumbar extensors, with strengthening of the abdomen (Fatemi et al., 2015; Kaple and Phansopkar, 2023). However, a post-test comparison of the outcome measures between both treatment groups revealed that the core stabilization program was significantly more effective in reducing the LSA. This finding suggests that targeted CSE may be more effective in addressing the musculoskeletal changes associated with obesity in adolescents (Skundric et al., 2021). In addition, the use of CSE may provide an added benefit through the emphasis on strengthening of deep trunk muscles, which play an important role in spinal stabilization and subsequent reduction of mechanical overload on the lumbar spine. In a similar vein, core stability training may help with musculoskeletal issues by improving postural control and subsequent reduction of mechanical stress to the lumbar spine, which is a precursor of chronic musculoskeletal dysfunction (Lee, 2021).

The lack of significant improvement in VAS scores, despite significant improvements in functional outcomes, may reflect the multidimensional nature of pain and the limitations of using a single self-reported measure of pain intensity. The visual analogue scale (VAS), while widely used, primarily captures pain intensity at a specific time point and may not fully reflect changes in pain perception or its functional impact. The use of additional validated pain assessment tools with different psychometric properties may have provided a more comprehensive understanding of pain-related outcomes following the intervention (Camacho-Navas et al., 2026).

4.1. Limitations of the study

There were important limitations to the study: no electromyography and ultrasound were used to assess deep core muscles. The relatively small sample size may limit the generalizability of the findings to the broader population of adolescents with central obesity and chronic low back pain. The fact that neither the participants nor the therapists were blinded to the treatment programs increased the chances of performance bias. However, the outcome assessors were blinded, which reduced detection bias and increased reliability between groups. The limited focus on short-term results prevents any conclusions regarding long-term effects. Future studies should focus on longer follow-ups, confounding factors, and standardized protocols with objective biomechanical assessments to reduce biases and better understand how LSA changes with central obesity. Additionally, future studies should incorporate a more comprehensive and up-to-date literature base to further support and contextualize the findings. Although core stabilization exercises demonstrated greater improvements in lumbosacral angle and functional disability compared with conventional physical therapy, pain reduction did not differ significantly between groups. Therefore, the findings should be interpreted with caution, as the observed benefits appear to be primarily related to spinal alignment and functional outcomes rather than pain reduction alone.

5. Recommendations

Future research is recommended to include an additional group receiving a combined intervention of core stabilization and Williams flexion exercises to further explore potential additive or synergistic effects between both exercise approaches. Future studies should also incorporate longer-term follow-up assessments and monitor physical activity levels, dietary habits, body weight, and changes in obesity status during the intervention period to better control for potential confounding factors and provide a more comprehensive understanding of treatment outcomes.

6. Conclusion

The structured core stabilization exercise program is more effective than conventional physical therapy in improving the LSA and reducing functional disability among centrally obese adolescents with chronic LBP. While both methods offer pain relief, core stabilization exercises are particularly beneficial in enhancing spinal alignment and overall functionality. Therefore, these exercises should be included as a crucial part of the treatment plan for such patients. These findings highlight the need for individualized core stability training for this particular group of patients.

Data availability

Data, including raw data or any supporting materials, can be obtained from the corresponding author upon request.

Funding information

None.

CRediT authorship contribution statement

Marian M. Shafeek: Project administration, Resources, Supervision, Writing – original draft. **Ahmed S. Ali:** Conceptualization, Methodology. **Hanan Hosny M. Battesha:** Validation, Visualization, Writing – review & editing. **Noha Aly Mohamed:** Funding acquisition, Methodology. **Ahmed Mahmoud Hamed Hasnin:** Visualization. **Sami kamal Mohamed Elgendy:** Project administration, Resources. **Ibrahim M. Abdelhakim:** Investigation, Methodology.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: There were no declared conflicts of interest.

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