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Research Protocol

Physiotherapy Section

Effect of Sensor Monitored Upright Sitting on Core Muscle Thickness, Contractibility and Spinal Posture among Asymptomatic University Students: A Study Protocol for RCT

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ABSTRACT

Introduction: Prolonged sitting in classrooms predisposes students to poor posture, muscle imbalance, and low back pain. Tonic activation of the core muscles that stabilise the spine increases when seated upright, and this may have positive effects on pulmonary function and overall wellbeing.

Need of the study: Although there is extensive literature on upright sitting activating the core, little is known about upright sitting as an intervention for core strengthening compared with conventional exercises in asymptomatic students with core weakness. Hence, this study aims to determine and compare the effect of four weeks of upright sitting as an intervention.

Aim: To compare the effects of four weeks of sensor-monitored upright sitting, conventional exercises, and a combination of upright sitting and conventional exercises on core strength, as measured by the plank test, surface Electromyography (EMG), and ultrasonography, in asymptomatic university students with core weakness.

Materials and Methods: This is a randomised three-arm, assessor-blinded controlled trial that will be conducted in the physiotherapy department of a tertiary-care hospital in North Karnataka, India. A total of 120 university students with core weakness, aged 18 to 25 years, will be randomly assigned to one of three groups: upright sitting group; conventional exercises group; or combined upright sitting and conventional exercises group. Ethical clearance for the study was obtained from the KAHER Ethics Committee (KAHER/EC/24-25/417). The outcome include plank hold test to evaluate the core endurance, surface EMG to assess muscle contractability and ultrasonography to assess muscle thickness, Forced Vital Capacity (FVC), and Forced Expiratory Volume in one second (FEV1) ratio by portable spirometer and posture by Artificial Intelligence Posture Evaluation and Correction System (APCES) application, will be assessed at pre, post 4th week. Follow-up assessment of core endurance by plank hold test will be done at the end of 8th week. Data will be analysed using Statistical Package for the Social Sciences (SPSS) version 28.0. Descriptive statistics will include frequency, percentage, mean, and standard deviation. Chi-square test will be used for association. Repeated-measures Analysis of Variance (ANOVA) (or mixed-design ANOVA) will be used to assess differences over time, followed by appropriate post hoc procedures. For normally distributed data, independent t-tests (between groups) and paired t-tests (within groups) will be used; for non normally distributed data, Mann-Whitney U tests (between groups) and Wilcoxon signed-rank tests (within groups) will be used. A significance level of 0.05 will be used.

Keywords: Exercises, Muscle strength, Posture, Prevention, Spine health

INTRODUCTION

Over the years, physical activity has declined significantly due to increased reliance on technology, prolonged classroom sitting, workplace setups, and modern transportation. The widespread use of televisions, computers, mobile devices, and video games has further contributed to a sedentary lifestyle [1,2]. Additional factors such as obesity and maintaining static postures for extended periods also play a role. Muscular imbalances are often linked to poor workplace posture, insufficient exercise, weak abdominal or back muscles, and underlying structural deformities, all of which can lead to various musculoskeletal issues [3,4]. These imbalances are major contributors to an increased risk of low back pain, reduced muscle endurance, uneven muscle function, and increased strain on the back and lumbar spine [3].

Sitting is the most commonly adopted position for many daily activities. Prolonged sitting has been linked to decreased endurance of lower back muscles, tightness in the pelvic muscles, and the development of low back pain [2]. Research indicates that adolescents typically spend between 60-80% of their school day seated, with many starting to experience low back pain—a problem that becomes more common as they get older [5,6]. Various sitting positions are used, such as upright sitting, slumped sitting, leaning forward, and leaning backward [7]. The way a person sits can influence trunk muscle activity, with different postures activating specific muscle groups more than others [8-10].

The lumbo-pelvic upright sitting posture, characterised by an anterior tilt of the pelvis, lumbar lordosis, and a relaxed thorax, elicits sustained activity in the transverse portion of the Internal Oblique (IO), the superficial lumbar multifidus, and, in some cases, the thoracic erector spinae muscles [8-10]. This pattern suggests that these muscles play a key role in postural stabilisation [10]. Recent research has also shown that even in healthy individuals, prolonged slumped sitting leads to muscular fatigue in the trunk muscles [9]. Studies have shown that slumped sitting significantly reduces the activity of the IO and Transversus Abdominis (TrA) muscles compared to upright sitting [8,9,11]. While the literature has examined core muscle activation during upright sitting, it has not extensively explored using upright sitting as a specific intervention [8-10,12-14].

Conventional exercises, primarily focused on strength and resistance training, have long been utilised to address core muscle weakness. These exercises have been shown to be effective in enhancing core muscle strength [2,15]. Several factors can hinder adherence to conventional exercise programs, including low self-efficacy, fear of pain, and difficulty incorporating exercises into daily routines.

Recent advancements, such as sensors, offer effective solutions for monitoring spinal movement. In particular, inertial sensors are widely used to assess lumbo-pelvic posture during sitting [16]. These sensors can be conveniently worn as apparel or accessories, enabling portable and personalised data processing. They provide unobtrusive, continuous monitoring of body position [17].

In recent years, younger individuals have become increasingly susceptible to low back pain [18]. This trend is largely attributed to the significant amount of time this population spends sitting, whether in classrooms or while gaming, which places them at greater risk for poor posture, muscle imbalances, and subsequent low back pain [8-10,19-21]. Systematic reviews indicate that the lifetime prevalence of back pain—including both lower back and thoracic pain—can reach up to 66% in India [22,23]. Given these points, the aim of this study is to evaluate the effects of sensor-monitored upright sitting over a four-week period on core muscle thickness, contractility, and spinal posture in asymptomatic individuals with core muscle weakness.

REVIEW OF LITERATURE

Sitting posture can affect trunk muscle activity, and different muscles are predominantly stimulated depending on the sitting posture, such as upright sitting, slumped sitting, leaning forward, and leaning backward [8-10]. The literature also suggests that the tonic activation of the core muscles that maintain the spine increases when seated upright in a chair [8], and there is a positive effect on pulmonary function and overall wellbeing [24-27]. Given the immediate effect of upright sitting on core muscles in the literature, there is a dearth of literature on introducing upright sitting as an intervention to strengthen the core muscles, to our knowledge.

Several studies highlight the role of sitting posture in activating trunk muscles and supporting core stability [8,28,29]. A systematic review highlighted that while core exercises aid recovery from sitting-induced fatigue, there is limited evidence on their effects on deep stabilisers like the Transversus Abdominis (TrA) [30]. Kett AR et al., found that slumped sitting increases lumbar stiffness, whereas upright sitting with frequent micro-adjustments helps reduce it [27]. Meanwhile, a study by Dickin et al., demonstrated that using unstable sitting surfaces, such as stability balls, subtly increases core and leg muscle engagement and raises energy expenditure [31]. Together, these findings suggest that adopting upright or dynamic sitting postures may offer a low-intensity strategy for enhancing core muscle activation and preventing musculoskeletal discomfort [32-34].

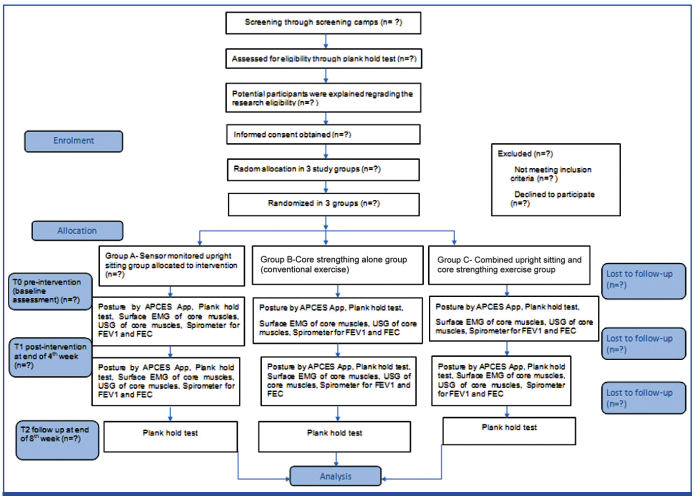
MATERIALS AND METHODS

The SPIRIT reporting guidelines are used to report this study protocol [Annexure 1]. The trial is reported in accordance with the CONSORT 2010 statement and feasibility trial guidelines [Table/Fig-1] [Annexure 2].

Trial design: The current study is a randomised triple-arm, assessor-blinded controlled trial to be conducted in a tertiary-care hospital and health sciences university college setting across North Karnataka for two years. Ethical clearance for the study has been obtained from the KAHER Ethics Committee (KAHER/EC/24-25/417). The study participants will be allocated randomly into three study groups. It is prospectively registered in CTRI with trial registration number CTRI/2025/01/079014. https://ctri.nic.in/Clinicaltrials/regtrial.php?modid=1&compid=19&EncHid=87909.13449.

Inclusion criteria: Asymptomatic university students aged 18-25 years, with core muscle weakness as measured by the plank hold test [35,36], scoring below average (30-60 seconds) will be included in the study.

Exclusion criteria: Participants diagnosed with musculoskeletal or systemic disorders that affect posture or pulmonary function, are



[Table/Fig-1]: CONSORT 2025 flow diagram.

currently participating in any strength-training exercise program, have diagnosed physical disabilities, or have any other medical or surgical condition that would prevent participation in the exercise program.

Sample size: The present study sample size was calculated based on previous studies evaluating core endurance. The required sample size was estimated using outcome measures such as muscle strength and muscle thickness. Standard deviations are S1=10.20 and S2=12.50 mean difference between 1st and 2nd sample =10.55, alpha error (%) =95.

(The mean difference (10.55) reflects the arithmetic gap between the central tendency of the two sitting posture groups, and the standard deviations (S_1 and S_2) were approximated by measuring the extent of variability illustrated in the error bars on each graph.) With these available values and assumptions, the following formula was applied: $n=2S^2(Z_{1-\alpha}+Z_{1-\beta})^2/d^2$. Where, $Z_{1-\alpha}$= Z-value for α level (2.58 at 1% α error or 99% confidence, $Z_{1-\beta}$= Z-value for β level (1.2820 at 10% β error or 90% power, d=Margin of error=10.55, S=Pooled SD= (S1+S2)/2. Hence, the sample size was calculated as 40 in each group. Considering 10% drop out rate [8].

Recruitment method: Participants will be screened through screening camps across colleges within the ambit of the Healthcare University in North Karnataka and invited to participate. After explaining the study procedure, interested individuals will be screened further for eligibility, and those eligible will be enrolled. The study procedures will be explained in detail before enrollment.

Randomisation method: All eligible participants will be randomly assigned to three groups: sensor-monitored upright sitting (Group A), core strengthening (Group B), and combined upright sitting and core strengthening (Group C). All healthcare colleges under KAHER University will be enlisted and assigned cluster numbers. Random selection will be used to select the clusters. Participants will be screened from randomly selected clusters, and eligible participants will be recruited. Computer-generated random numbers (Random.org) will be used to allocate participants to the groups.

Blinding: This is an assessor- and statistician-blinded study. The assessor and the statistical analyst will be blinded to group assignments by coding the groups as Group A, Group B, and Group C. Participants and intervention providers will not be blinded due to the nature of the interventions.

Parameters studied: Core muscle endurance will be evaluated by the plank hold test, contractility by surface EMG of core muscles, and core muscle thickness by ultrasonography. Secondary parameters include Vital Capacity (VC), Forced Vital Capacity (FVC), and Forced Expiratory Volume in one second (FEV1) measured with a portable spirometer, and posture assessed via the APCES application. The total duration for recording all parameters will be 40-50 minutes, documented one day prior to the intervention. All study parameters will be assessed at baseline (T0), at the end of four weeks (T1), and the plank hold test will be reassessed at the end of eight weeks (T2) to assess any carryover effect.

Study intervention: The study quality will be maintained by applying the Consensus on Exercise Reporting Template (CERT) guidelines/checklist [Annexure 3]. After eligibility screening, all participants will receive an orientation session regarding the study intervention. They will be asked about their availability for one hour of sessions on alternate days over four weeks to proceed with the intervention.

Group A- Sensor monitored upright sitting group: An orientation on proper sitting posture will be delivered by a qualified physiotherapist, explaining upright sitting with the hips and knees at 90°, feet shoulder-width apart, and arms relaxed at the sides, in a position unsupported on a stool. Participants will adopt upright sitting, and the thoracic angle will be measured with an inclinometer to confirm upright sitting (approximately 20-40 degrees) [37]. A custom-made upright-sitting monitoring sensor device, developed by a professor from the Department of Electronics and Communication, Jain College of Engineering and Research, Belagavi, will be attached at the thoracic level to monitor the duration of maintained posture. Sessions will be conducted three times per week, supervised for a maximum of one hour per day for two weeks, with a gradual increase in upright-sitting duration up to two hours per day over the four weeks. Data from sensor readings corresponding to non upright positions will be omitted [Table/Fig-2] [38-42].

Wearable posture monitoring and corrective device: A wearable posture-monitoring device was designed to detect posture in real time, using a microcontroller to process accelerometer data and generate real-time feedback signals. The device's validity and reliability will be tested by comparing its results with an inclinometer to detect spinal deviation at calibrated angles at the start of the study.

Group B- Conventional exercises: One orientation session will be conducted for study participants before beginning the intervention, during which the exercise protocol will be explained in detail. A total of three exercise sessions will be provided per week for four weeks. All exercises will be performed for 10 repetitions with appropriate rest between each set. The total duration of the intervention will be 40 minutes. Progression will include adding a hold in the exercise position from week 2. Hold duration will be increased from five seconds to eight seconds by week 4 [Table/Fig-3] [38,43-48].

Exercise protocol: One-leg sliding; supine lying leg lifts; crook-lying with crunches; knee-to-chest; static back; pelvic bridging; lumbar spine rotation; prone lying - leg lifts; cat and camel exercises; prone lying trunk lifts. Each of these exercises will be performed for 10 repetitions.

Group C- Conventional exercises and upright sitting: In Group C, study participants will receive both upright sitting and conventional exercises [Table/Fig-4] [38,42,44-48].

Concomitant care: All exercise sessions will begin with warm-up and end with cool-down exercises. Home exercise sessions will last 30-60 minutes, with proper breaks in between. Sensor-monitored upright sitting will be performed at the participants' convenience, either in the library or in the institute's exercise hall. Core-strengthening exercises will be conducted in a large exercise therapy hall on the institute premises.

Adherence to the interventions: Participants will receive a logbook with detailed descriptions of the upright sitting and exercises. They will be asked to record completion after each session. The records will be reviewed weekly, and reminder messages will be sent to ensure adherence to the protocol.

Criteria for dropout: Participants who miss 20% of the sessions (i.e., three sessions out of 12), miss the follow-up evaluation, or are unwilling or unable to continue in the study for any health reason will be considered dropouts.

Criteria for protocol modification: The protocol will be modified only if there are reported adverse events during the study. Any such modification, if considered, will be sought with prior permission from the Research and Ethics Committee.

Data collection procedure: Outcome measures will be assessed by a qualified physiotherapist. Demographic details such as age, height, weight, BMI, etc., will be recorded along with baseline assessments [Table/Fig-5].

Primary outcomes measure: Primary outcome measure: Plank hold test [34,35].

Before beginning the plank test, the subject lies on their stomach with legs straight and weight evenly distributed between the toes and the elbows/forearms. A straight line from head to toe is maintained when the hips are raised off the ground. The subject should look downward toward the ground. When the participant is in the appropriate posture, start the stopwatch. The test ends when the participant is no longer able to maintain a straight back, causing the hips to drop or rise. The held time is the score. This will be assessed at T0 (baseline), T1 (end of 4 weeks), and T2 (end of 8 weeks).

Ultrasonography for muscle thickness [49] (Will be performed by the radiologist): Performed by a radiologist. For anterolateral abdominal wall muscles {Transversus Abdominis (TrA), Internal Oblique (IO), External Oblique (EO)}, place the ultrasound transducer

Variables	Week 1	Week 2	Week 3	Week 4
Intensity	Beginner low intensity	Beginner low intensity	Intermediate low to moderate intensity	Intermediate low to moderate intensity
Sensor monitored upright sitting	1 hour supervised session, 3 times a week	1 hour supervised session, 3 times a week	1.5 hour supervised session, 3 times a week	2 hour supervised session, 3 times a week
Activities while maintaining the upright sitting	Reading, computer related work	Reading, computer related work	Typing, Writing, talking, rotation without loosing the upright posture	Typing, Writing, talking, rotation without loosing the upright posture
Single exercise bout time	1 hour+ rest periods	1 hour+ rest periods	1.5 hours+rest periods	2 hours+ rest periods
Total exercise time	60 mins+ rest periods	60 mins+ rest periods	90 mins+ rest periods	120 mins+ rest periods
Recovery time	5 min	5 min	5 min	5 min
Cool down exercises type	Deep breathing exercises	Deep breathing exercises	Deep breathing exercises	Deep breathing exercises
Cool down exercise time	5 min	5 min	5 min	5 min
Supervised sessions per week	3 sessions per week	3 sessions per week	3 sessions per week	3 sessions per week
Home exercises	Practice upright sitting min-2 sessions per week	Practice upright sitting min-2 sessions per week	Practice upright sitting min-2 sessions per week	Practice upright sitting min-2 sessions per week
Frequency	5 sessions per week	5 sessions per week	5 sessions per week	5 sessions per week

[Table/Fig-2]: Upright sitting protocol (for Group A).

Variables	Week 1	Week 2	Week 3	Week 4
Intensity	Beginner {(60% of Maximum Heart Rate (MHR)}	Beginner (65% of MHR)	Intermediate (75% of MHR)	Intermediate (85% of MHR)
Warm up (types/ time)	General mobility exercises/ Stretching (10 min)	General mobility exercises/ Stretching (10 min)	General mobility exercises/ Stretching (10 min)	General mobility exercises/ Stretching (10 min)
Types of exercises	Core strengthening exercises like-single leg lift, double leg lifts, static back, pelvic bridge, abdominal crunches, spine rotation exercises, prone leg lifts, upper trunk lifts, cat and camel exercises	Core strengthening exercises like-single leg lift, double leg lifts, static back, pelvic bridge, abdominal crunches, spine rotation exercises, prone leg lifts, upper trunk lifts, cat and camel exercises	Core strengthening exercises like-single leg lift, double leg lifts, static back, pelvic bridge, abdominal crunches, spine rotation exercises, prone leg lifts, upper trunk lifts, cat and camel exercises	Core strengthening exercises like-single leg lift, double leg lifts, static back, pelvic bridge, abdominal crunches, spine rotation exercises, prone leg lifts, upper trunk lifts, cat and camel exercises
Single exercise bout time	2 min	2 min	2 min	2 min
Exercise series (n)	1 set with 10 repetition (5 sec hold time for each exercises)	1 set with 10 repetition (5 sec hold time for each exercises)	2 set with 8 repetition (8 sec hold time for each exercises)	2 set with 10 repetition (10 sec hold time for each exercises)
Total exercise time	30 min	30 min	40 min	45-50 min
Recovery time	5 min	5 min	5 min	5 min
Cool down exercises type	Stretching and deep breathing exercises	Stretching and deep breathing exercises	Stretching and deep breathing exercises	Stretching and deep breathing exercises
Cool down exercise time	10 min	10 min	10 min	10 min
Supervised sessions per week	3 sessions per week	3 sessions per week	3 sessions per week	3 sessions per week
Home exercises	1 sessions per week (same exercises)	1 sessions per week (same exercises)	1 sessions per week (same exercises)	1 sessions per week (same exercises)
Frequency	4 sessions per week	4 sessions per week	4 sessions per week	4 sessions per week

[Table/Fig-3]: Core strengthening exercise protocol (for Group B).

Variables	Week 1	Week 2	Week 3	Week 4
Intensity	Beginner (60% of MHR)	Beginner (65% of MHR)	Intermediate (75% of MHR)	Intermediate (85% of MHR)
Warm up (types/ time)	General mobility exercises/ Stretching (10 min)	General mobility exercises/ Stretching (10 min)	General mobility exercises/ Stretching (10 min)	General mobility exercises/ Stretching (10 min)
Types of exercises	Core strengthening exercises like-single leg lift, double leg lifts, static back, pelvic bridge, abdominal crunches, spine rotation exercises, prone leg lifts, upper trunk lifts, cat and camel exercises	Core strengthening exercises like-single leg lift, double leg lifts, static back, pelvic bridge, abdominal crunches, spine rotation exercises, prone leg lifts, upper trunk lifts, cat and camel exercises	Core strengthening exercises like-single leg lift, double leg lifts, static back, pelvic bridge, abdominal crunches, spine rotation exercises, prone leg lifts, upper trunk lifts, cat and camel exercises	Core strengthening exercises like- single leg lift, double leg lifts, static back, pelvic bridge, abdominal crunches, spine rotation exercises, prone leg lifts, upper trunk lifts, cat and camel exercises
Sensor monitored upright sitting	1 hour supervised session, 3 times a week	1 hour supervised session, 3 times a week	1 hour supervised session, 3 times a week	1 hour supervised session, 3 times a week
Single exercise bout time	2 min	2 min	2 min	2 min
Exercise series (n)	1 set with 10 repetition (5 sec hold time for each exercises)	1 set with 10 repetition (5 sec hold time for each exercises)	2 set with 8 repetition (8 sec hold time for each exercises)	2 set with 10 repetition (10 sec hold time for each exercises)
Total exercise time	1 hour 30 min	1 hour 30 min	1 hour 40 min	1 hour 45-50 min
Recovery time	10 min	10 min	10 min	10 min
Cool down exercises type	Stretching and deep breathing exercises	Stretching and deep breathing exercises	Stretching and deep breathing exercises	Stretching and deep breathing exercises
Cool down exercise time	10 min	10 min	10 min	10 min
Supervised sessions per week	3 sessions per week	3 sessions per week	3 sessions per week	3 sessions per week
Home exercises	1 sessions per week (core exercises with upright sitting)	1 sessions per week (core exercises with upright sitting)	1 sessions per week (core exercises with upright sitting)	1 sessions per week (core exercises with upright sitting)
Frequency	4 sessions per week	4 sessions per week	4 sessions per week	4 sessions per week

[Table/Fig-4]: Core strengthening along with upright sitting protocol (for Group C).

	Enrolment	Allocation	Close-out		
Time point**	-t1	0	T0/ Baseline	T2/ Week 4	T3/week 8
Enrolment:					
Eligibility screen	X				
Informed consent	X				
(List other procedures)	X				
Allocation		X			
Interventions:					
(Sensor monitored upright sitting A)			X	X	

(Core strengthening exercises B)			X	X	
(Combined upright sitting and core strengthening C)			X	X	
Assessments:					
(Plank hold test)	X	X	X	X	X
(USG of core muscles)			X	X	
(Surface EMG of core muscles)			X	X	
(Posture by APCES App)			X	X	
(Ratio of FEV1 to FEC)			X	X	

[Table/Fig-5]: Template of recommended content for the schedule of enrolment, interventions, and assessments.
*Recommended content can be displayed using various schematic formats. See SPIRIT 2013 Explanation and Elaboration for examples from protocols.
**List specific timepoints in this row

transversely across the right side of the abdominal wall along the anterior axillary line, midway between the 12th rib and the iliac crest, to obtain a clear image of the deep abdominal layers. For the anterior abdominal wall muscle {Rectus Abdominis (RA)}, place the transducer 2-3 cm above the umbilicus, 2-3 cm from the midline. For the erector spinae: in the prone position, place the ultrasound probe longitudinally 4 cm lateral to the L4 spinous process. This will be assessed at T0 (baseline) and T1 (post-intervention at the end of week 4).

Surface EMG analysis [50]: EMG analysis will be performed for the following muscles: thoracic erector spinae (5 cm lateral to the T9 spinous process), external oblique (just below the rib cage, along the line connecting the most inferior costal margin and the contralateral pubic tubercle), IO (1 cm medial to the anterior superior iliac spine), and RA (1 cm above the umbilicus and 2 cm lateral to midline). To minimise skin impedance, remove hair over the target muscles and wipe the skin with alcohol swabs before attaching the electrodes. The participant will be positioned supine with legs straight and strapped with a belt. A resisted curl-up will be used for the left and right RA. A curl-up with the right shoulder moving toward the left targets the left IO and right EO; the same procedure will be repeated on the opposite side to target the right IO and left EO. The average of three trials will be used. A normalisation technique for all three back muscles will be used with the participant in a prone position, legs straight, and strapped with a belt, hands placed behind the neck. The participant will lift the head, shoulders, and elbows just off the floor. This will be assessed at T0 (baseline) and T1 (post-intervention at the end of week 4).

Secondary Outcome Measures

Spirometer [51]: Participants will be instructed to take a maximal inspiration, then place their mouth directly around the mouthpiece (no air filter) and perform a maximal expiration for as long as possible. Examinations will include VC, FVC, and FEV1. These will be assessed at baseline (T0, pretreatment) and post-intervention at the end of the 4th week (T1).

Posture Evaluation by APECS App [52]

Procedure: Participants will be in a standing position. Photographs will be taken from the front and back views and uploaded to the software. Based on the markers, a quick basic posture analysis will be performed. This will be assessed at baseline (T0) and post-intervention at the end of the 4th week (T1).

Safety Monitoring

The study participants are healthy individuals without any diagnosed physical or mental illness. The exercises will be supervised by a qualified physiotherapist. The expected adverse event is muscle soreness due to exercise, which will be managed with adequate rest and hot fomentation (heat therapy).

Data Management

Data will be entered into MS Excel and tabulated in a spreadsheet, ensuring anonymity. The records will be stored securely, with access limited to the principal investigator. Group allocations will be coded with letters (A, B, and C) to maintain blinding during statistical analysis. The study data will be shared only after coding and de-identification of the participants.

STATISTICAL ANALYSIS

Software used will be SPSS version 28.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics: Frequency, percentage, mean, and standard deviation.Inferential statistics: Chi-square tests for associations; one-way ANOVA with repeated measures for differences, followed by appropriate post hoc procedures.Between- and within-group comparisons: Independent t-tests and paired t-tests for normally distributed data. Non-normally distributed data: Mann-Whitney U test and Wilcoxon signed-rank test.Significance: A significance level of 0.05 will be used.

Missing Data

Missing data will be evaluated for patterns and extent of missingness. Data will be screened to determine whether they are Missing Completely At Random (MCAR), Missing At Random (MAR), or Not At Random (MNAR). For data found to be MCAR or MAR, appropriate imputation techniques (e.g., multiple imputation or mean/median substitution) will be applied based on the nature of the variable.

Informed consent: All study participants will be required to sign a written informed consent. They will receive a patient information sheet in their vernacular language. If they have any questions, the principal investigator will be available to help clarify them.

Confidentiality: The information collected from study participants will be kept confidential. All information will be coded and de-identified before publication or presentations. Data will be stored electronically and protected by password.

Expected outcomes: The study outcomes will indicate whether upright sitting, conventional exercises, or a combined intervention is more effective for core strength. The study results may also contribute to the literature on muscle strength when upright sitting is practiced for four weeks. The study may pave the way to prevent consequences of muscular imbalance and related musculoskeletal problems, such as back pain and altered body mechanics due to weak muscles.

Trial status: The study is open for recruitment, with about 20% of recruitment completed. The enrollment is estimated to finish by December 2025.

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Disclosure statement: The APECS application-research support has agreed to allow us to use the paid version of the software for posture evaluation. They had no input into the study design or

protocol writing and have no role in the authors' decisions to submit or publish the report.

Conflict of interest: The APECS application-research support has provided access to the paid version of the software for posture evaluation; however, they have no role in the study design or protocol.

Dissemination policy: The study results and outcomes will be published in peer-reviewed journals. Authorship will be determined based on each author's contribution.

Availability of data and materials: The study data will be available on request. After data collection is complete, it will be deposited in Mendeley Data.

Study Sponsor and Role

The study is self-funded, and no financial support is received by any authors. The APECS application-research support has provided the paid software for posture evaluation; they have no role in study design or protocol.

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