

EFFECT OF UPRIGHT SITTING VERSUS CONVENTIONAL CORE EXERCISE ON REGIONAL POSTURAL ALIGNMENT IN UNIVERSITY STUDENTS: A SECONDARY ANALYSIS OF A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Upright sitting is widely recommended for postural health but has rarely been prescribed and monitored as an intervention. Whether it improves measured postural alignment more than conventional core exercise is unknown.

Objective: To compare the effects of upright sitting, conventional core exercise, and their combination on regional postural alignment in university students with core muscle weakness.

Methods: Secondary analysis of a three-arm, parallel-group randomized controlled trial. One hundred and twenty asymptomatic university students aged 18–25 years with core muscle weakness were allocated equally to upright sitting (Group A), conventional core exercise (Group B), or both (Group C) for four weeks. Frontal-plane alignment of the head, shoulders, pelvis, knees and feet was scored from standardised anterior and posterior photographs using the APECS photogrammetric application at baseline and four weeks, with lower scores indicating better alignment. Group-by-time interaction was assessed by mixed-model analysis of variance. Within-group change was tested by Wilcoxon signed-rank test and between-group change by Mann–Whitney U test with Bonferroni adjustment, with Cohen's d as the effect size.

Results: All 120 participants completed both assessments. Groups were comparable at baseline in all five regions. Alignment improved significantly in every group in every region (all $p \leq 0.003$). A significant group-by-time interaction was found for shoulder alignment (partial $\eta^2 = 0.101$), knees alignment (0.076), head tilt (0.066) and pelvic tilt (0.063). Upright sitting produced greater improvement than conventional exercise in head tilt ($Z = 2.780$, $p = 0.006$, $d = 0.653$) and greater improvement than combined training in shoulder alignment ($Z = 3.415$, $p < 0.001$, $d = 0.813$) and pelvic tilt ($Z = 2.975$, $p = 0.003$, $d = 0.626$). Conventional exercise produced greater improvement than upright sitting at the knees alignment ($Z = 3.175$, $p = 0.002$, $d = 0.755$). Feet did not differ between groups.

Conclusions: Upright sitting improved frontal-plane alignment of the head, shoulders and pelvis more than conventional core exercise or combined training, while conventional exercise improved knees alignment more. Each intervention produced its largest effect in the regions it directly engaged, and postural benefit did not follow the pattern of muscular benefit reported for this trial elsewhere.

KEYWORDS: Posture, Sitting position, Photogrammetry, Randomized controlled trial, Postural asymmetry, Students

1. INTRODUCTION

Prolonged seated study is characteristic of university life. Undergraduates have been reported to sit for approximately eleven hours daily [1], and meta-analytic evidence links sedentary behaviour to musculoskeletal pain across occupational and non-occupational settings [2]. Musculoskeletal complaints are correspondingly common in this population, with the neck, back and shoulders most frequently affected [3].

Advice to sit upright is among the most commonly given ergonomic recommendations, and there is a mechanistic basis for it, different upright sitting postures produce distinct patterns of spinal-pelvic curvature and trunk muscle activation compared with slumped sitting [4,5]. That advice has nonetheless rarely been tested as an intervention. Upright sitting has been studied largely as a momentary laboratory condition rather than as something prescribed, [6] accumulated and verified over weeks. The practical obstacle has been measurement. Without a means of recording how long a person actually maintains a prescribed posture, upright sitting cannot be dosed and therefore cannot be trialled.

Wearable sensing addresses this obstacle. A cluster randomised trial of a lumbopelvic monitor and feedback device demonstrated that sensor-based monitoring can change postural behaviour in an occupational setting [7], but such devices have generally been applied to behaviour during a task rather than to accumulated postural dose as a prescribed intervention.

Conventional core strengthening is the established alternative. It applies intermittent, relatively high-load contractions and is well supported for improving trunk muscle strength and endurance. Whether it also improves measured postural alignment is less clear. A randomized comparison of progressive postural control exercise against core stability exercise in young adults found no significant difference between the two approaches on static postural control, despite differing effects on trunk muscle contractility [8].

The parent trial for this analysis compared upright sitting, conventional core exercise and their combination, with core muscle endurance as the primary outcome. The present paper reports the pre-specified postural outcome and addresses a

question the muscular outcomes cannot answer- whether an intervention that trains posture directly improves measured alignment more than one that trains muscle.

MATERIALS AND METHODS

Study design and ethics

This is a secondary analysis of a three-arm, parallel-group randomized controlled trial conducted at tertiary care Hospital, Belagavi, India. The trial was prospectively registered with the Clinical Trials Registry – India (CTRI/2025/01/079014) before enrolment of the first participant. Ethical approval was granted by the Institutional Ethics Committee on 4 November 2024 (reference KAH/EC/24-25/417) and all participants provided written informed consent. The study was conducted in accordance with the Declaration of Helsinki. Recruitment began on 21 January 2025 and the final assessment was completed on 16 February 2026. Reporting follows the CONSORT 2010 statement.

Participants

Asymptomatic university students of either sex aged 18–25 years were eligible if they demonstrated core muscle weakness, defined as a plank hold test score at or below the below-average reference band. Students were excluded if they had a diagnosed musculoskeletal or systemic disorder affecting posture or pulmonary function, were currently enrolled in an exercise training programme, had a physical disability, or had any other medical or surgical condition preventing participation in an exercise programme.

The sample size for the parent trial was calculated on muscle strength and thickness outcomes, using standard deviations of 10.20 and 12.50 and an expected mean difference of 10.55, with 1% alpha error and 90% power, yielding 40 participants per group and 120 in total. The postural outcome reported here was not the basis of this calculation.

Sampling, allocation and blinding

Participants were recruited by cluster sampling. All constituent colleges of the healthcare university were enumerated and assigned a cluster number, and clusters were selected using a random number table. Students within the selected clusters were screened for posture through APECS application. Eligible, consenting participants were individually assigned to one of the three groups using opaque sealed envelopes, giving 40 participants per group. The allocation sequence was generated by a statistician who took no part in recruitment or assessment. Participants were enrolled and assigned by the principal investigator.

Blinding was not undertaken. Participants and treating therapists could not be blinded given the nature of the interventions, and postural assessment was performed by the principal investigator, who was aware of group allocation. Photographs were captured and landmarks placed by the same assessor on both occasions, supporting internal consistency of technique but not removing the potential for expectation to influence landmark placement.

Interventions

All interventions ran for four weeks. Every participant attended a single orientation session at which the relevant protocol was demonstrated.

Group A – upright sitting. Participants sat unsupported on a stool with hips and knees at 90°, feet positioned shoulder-width apart and arms relaxed at the sides of the body. Upright sitting was defined by spinal inclination, with a lumbar angle of –15° to –20° and a thoracic angle of 20° to 40°. These angles were measured with a digital inclinometer at the orientation session, and each participant was positioned in the prescribed posture before the intervention period began. An inertial sensor worn at the lumbar level then recorded the time each participant maintained this posture, data recorded in any other sitting position were discarded. Participants returned to their habitual sitting position whenever they could no longer hold the prescribed posture.

Group B – conventional core exercise. One-leg sliding, supine leg lifts, crook-lying crunches, knee-to-chest, static back, pelvic bridging, lumbar spine rotation, prone leg lifts, cat and camel, and prone trunk lifts. Each exercise was performed for ten repetitions in one set with rest as required, giving a session of approximately 40 min. From the second week an end-range hold was added, progressing from five to eight seconds by the fourth week.

Group C – combined. Both protocols.

Adherence

Adherence was recorded in a study logbook. Groups A and C followed a progressive schedule of three times per week for four weeks. The upright sitting time for group A was progressed in terms of time they sat upright, and conventional exercises were progressed with intensity and repetitions. A separate logbooks were provided to maintain the adherence and all participants received regular telephone reminders.

Outcome measure

Postural alignment was assessed at baseline and at four weeks using the APECS application (AI Posture Evaluation and Correction System; New Body Technologies, Grenoble, France), a photogrammetric tool that computes postural indices from anatomical landmarks placed on standardised photographs. Application versions 8.5.6 and 8.5.20 were used over the course of the study, running on an Android smartphone. Photographs were taken in anterior and posterior views with the camera mounted on a tripod at approximately hip height, at a fixed distance of 3 m, with participants standing in the same marked position on each occasion. Images were uploaded to the application, which generated graded scores for five regions: head, shoulders, pelvis, knees and feet.

Because only anterior and posterior views were obtained, the measures reported here describe alignment in the frontal plane lateral tilt of the head, asymmetry of shoulder height, obliquity of the pelvis, and alignment of the knees and feet. Sagittal-plane characteristics such as forward head position or anterior pelvic tilt were not assessed. Lower scores denote

better alignment, so a reduction in score represents improvement. Scores are integers, the observed range across the sample was 0–7 for the head, 0–6 for the feet, and 0–4 for the remaining three regions. Normative data and reproducibility for this application in young healthy adults have been reported previously [9].

Statistical analysis

Analyses included all randomized participants. As the APECS outputs are ordinal integer scores, non-parametric tests were used for all group comparisons.

Normality was assessed using the Shapiro–Wilk test and homogeneity of variance using Levene's test. Postural variables departed from normality in the majority of comparisons, and variances were heterogeneous for pelvic tilt ($F = 5.511$, $p = 0.005$) and knees ($F = 4.383$, $p = 0.015$). Baseline comparability across the three groups was examined using the Kruskal–Wallis test. Group-by-time interaction was assessed by mixed-model analysis of variance with time as the within-subject factor and group as the between-subject factor, with partial eta-squared as the effect size. Within-group change from baseline to four weeks was tested using the Wilcoxon signed-rank test.

Between-group comparison was performed on change scores using the Mann–Whitney U test, with Bonferroni adjustment across the three pairwise contrasts within each region ($\alpha = 0.0167$). Cohen's d was calculated on change scores and interpreted as small (0.2), medium (0.5) or large (0.8). Z statistics incorporate correction for tied ranks.

Analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Significance was set at 5%, two-tailed.

RESULTS

Participants

Of 455 students screened, 335 were excluded: 190 demonstrated above-average core strength, 95 were attending a gymnasium, 26 declined to participate and 24 were unable to commit to the schedule. One hundred and twenty participants were randomized, 40 to each group, and all completed both postural assessments with no dropouts or losses to follow-up (Fig. 1).

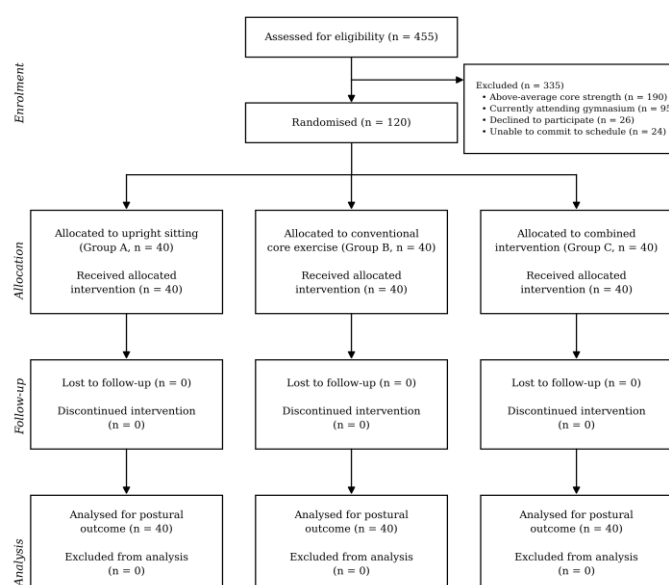


Fig. 1. Consort flow diagram.

Group A, upright sitting; Group B, conventional core exercise; Group C, combined intervention.

Participants were predominantly female (91 of 120), with a comparable sex distribution across groups ($p = 0.73$). Group C was older and had a higher body mass index than the other two groups (Table 1).

Table 1. Baseline characteristics.

Characteristic	Group A (n = 40)	Group B (n = 40)	Group C (n = 40)
Age (years), mean $\pm$ SD	21.9 $\pm$ 1.4	21.9 $\pm$ 1.4	23.6 $\pm$ 1.1*
Female, n (%)	29 (72.5)	30 (75.0)	32 (80.0)
Body mass index (kg/m ²)	21.7	21.4	23.3*
Head tilt	3.23 $\pm$ 1.94	2.88 $\pm$ 1.47	3.00 $\pm$ 1.65
Shoulder alignment	1.83 $\pm$ 0.71	1.73 $\pm$ 0.85	2.08 $\pm$ 1.07
Pelvic tilt	1.88 $\pm$ 1.36	1.20 $\pm$ 0.88	1.63 $\pm$ 1.39

Characteristic	Group A (n = 40)	Group B (n = 40)	Group C (n = 40)
Knees alignment	0.70 ± 0.88	0.98 ± 0.70	1.23 ± 1.21
Feet alignment	1.60 ± 1.08	1.48 ± 0.93	1.78 ± 1.51

Group A, upright sitting; Group B, conventional core exercise; Group C, combined. Postural values are APECS scores; lower scores indicate better alignment. * $p < 0.05$ across groups (Kruskal–Wallis). Sex distribution comparable (χ^2 , $p = 0.73$). All five postural regions comparable at baseline (all $p \geq 0.07$).

Baseline comparability

The three groups were comparable at baseline in all five postural regions: head tilt ($H = 1.074$, $p = 0.584$), shoulder alignment ($H = 3.150$, $p = 0.207$), pelvic tilt ($H = 4.264$, $p = 0.119$), knees ($H = 5.403$, $p = 0.067$) and feet ($H = 0.916$, $p = 0.632$). Baseline comparability across all five outcomes permits between-group comparison on change scores without the reservations that would otherwise apply.

Change within groups

Alignment improved significantly from baseline to four weeks in all three groups in all five regions (Table 2). Effect sizes were large in eleven of the fifteen comparisons and medium in the remaining four. The largest within-group effect was for shoulder alignment in Group A ($Z = 5.892$, $p < 0.001$, $d = -2.962$) and the smallest for the knees in the same group ($Z = 3.000$, $p = 0.003$, $d = -0.532$).

Table 2. Within-group change in postural scores from baseline to four weeks.

Variable	Grp	Baseline	Week 4	Z	p	Cohen's d
Head tilt	A	3.225 ± 1.941; 4 [2–5]	1.775 ± 1.625; 2 [0–3]	5.297	<0.001*	–1.714 (large)
	B	2.875 ± 1.471; 3 [2–4]	1.925 ± 1.685; 1 [1–3]	5.035	<0.001*	–1.402 (large)
	C	3.000 ± 1.649; 3 [2–4]	1.775 ± 1.165; 2 [1–3]	5.161	<0.001*	–1.531 (large)
Shoulder alignment	A	1.825 ± 0.712; 2 [1–2]	0.625 ± 0.774; 0 [0–1]	5.892	<0.001*	–2.962 (large)
	B	1.725 ± 0.847; 2 [1–2]	0.800 ± 0.853; 1 [0–1]	5.336	<0.001*	–1.616 (large)
	C	2.075 ± 1.071; 2 [2–3]	1.325 ± 0.888; 1 [1–2]	4.667	<0.001*	–1.120 (large)
Pelvic tilt	A	1.875 ± 1.362; 2 [1–3]	0.925 ± 1.141; 0 [0–2]	5.425	<0.001*	–1.720 (large)
	B	1.200 ± 0.883; 1 [1–2]	0.450 ± 0.749; 0 [0–1]	4.817	<0.001*	–1.190 (large)
	C	1.625 ± 1.390; 1 [1–2.25]	1.075 ± 0.829; 1 [0.75–2]	3.787	<0.001*	–0.770 (medium)
Knees alignment	A	0.700 ± 0.883; 0 [0–1]	0.475 ± 0.751; 0 [0–1]	3.000	0.003*	–0.532 (medium)
	B	0.975 ± 0.698; 1 [1–1]	0.400 ± 0.672; 0 [0–1]	4.796	<0.001*	–1.149 (large)
	C	1.225 ± 1.209; 1 [0–2]	0.700 ± 0.911; 0 [0–1]	3.827	<0.001*	–0.773 (medium)
Feet alignment	A	1.600 ± 1.081; 2 [0.75–2]	1.150 ± 0.975; 1 [0–2]	4.243	<0.001*	–0.893 (large)
	B	1.475 ± 0.933; 1 [1–2]	0.950 ± 0.959; 1 [0–1]	4.583	<0.001*	–1.038 (large)
	C	1.775 ± 1.510; 2 [0–3]	1.100 ± 0.955; 1 [0–2]	4.563	<0.001*	–0.973 (large)

Values are APECS scores, mean ± SD; median [interquartile range]. Lower scores indicate better alignment. Wilcoxon signed-rank test. * $p < 0.05$. Group A, upright sitting; Group B, conventional core exercise; Group C, combined.

Differences between groups

A significant group-by-time interaction was found for four of the five regions: shoulder alignment, $F(2,117) = 6.566$, $p = 0.002$, partial $\eta^2 = 0.101$; knees, $F(2,117) = 4.829$, $p = 0.010$, partial $\eta^2 = 0.076$; head tilt, $F(2,117) = 4.147$, $p = 0.018$, partial $\eta^2 = 0.066$; and pelvic tilt, $F(2,117) = 3.958$, $p = 0.022$, partial $\eta^2 = 0.063$. Feet improved in parallel across groups, $F(2,117) = 1.589$, $p = 0.208$ (Table 3). All four significant interactions were of medium magnitude.

Table 3. Group-by-time interaction.

Variable	F	p	Partial η^2	Effect
Head tilt	$F(2,117) = 4.147$	0.018*	0.066	Medium
Shoulder alignment	$F(2,117) = 6.566$	0.002*	0.101	Medium
Pelvic tilt	$F(2,117) = 3.958$	0.022*	0.063	Medium
Knees alignment	$F(2,117) = 4.829$	0.010*	0.076	Medium
Feet alignment	$F(2,117) = 1.589$	0.208	0.026	Not significant

Mixed-model analysis of variance. Partial η^2 : 0.01 small, 0.06 medium, 0.14 large. * $p < 0.05$.

Head tilt improved more in Group A than in Group B ($Z = 2.780$, $p = 0.006$, $d = 0.653$). Shoulder alignment improved more in Group A than in Group C ($Z = 3.415$, $p < 0.001$, $d = 0.813$), as did pelvic tilt ($Z = 2.975$, $p = 0.003$, $d = 0.626$). Knees improved more in Group B than in Group A ($Z = 3.175$, $p = 0.002$, $d = 0.755$). Feet did not differ between any pair of groups (all $p \geq 0.167$). Remaining contrasts, including shoulder alignment between Groups A and B ($p = 0.019$) and knees between Groups A and C ($p = 0.037$), did not reach the Bonferroni-corrected threshold (Table 4).

Table 4. Between-group comparison of change scores.

Variable	A vs B (Z; p; d)	A vs C (Z; p; d)	B vs C (Z; p; d)
Head tilt	A>B: $Z = 2.780$; $p = 0.006^*$; $d = 0.653$	A>C: $Z = 1.240$; $p = 0.217$; $d = 0.273$	C>B: $Z = 1.533$; $p = 0.127$; $d = 0.371$
Shoulder alignment	A>B: $Z = 2.348$; $p = 0.019$; $d = 0.555$	A>C: $Z = 3.415$; $p < 0.001^*$; $d = 0.813$	B>C: $Z = 1.342$; $p = 0.181$; $d = 0.281$
Pelvic tilt	A>B: $Z = 1.559$; $p = 0.120$; $d = 0.337$	A>C: $Z = 2.975$; $p = 0.003^*$; $d = 0.626$	B>C: $Z = 1.580$; $p = 0.115$; $d = 0.297$
Knees alignment	B>A: $Z = 3.175$; $p = 0.002^*$; $d = 0.755$	C>A: $Z = 2.090$; $p = 0.037$; $d = 0.530$	B>C: $Z = 0.804$; $p = 0.424$; $d = 0.084$
Feet alignment	B>A: $Z = 0.667$; $p = 0.508$; $d = 0.149$	C>A: $Z = 1.386$; $p = 0.167$; $d = 0.371$	C>B: $Z = 0.782$; $p = 0.438$; $d = 0.247$

Mann–Whitney U test on change scores. The group named first in each cell showed the greater improvement. * Significant at the Bonferroni-corrected $\alpha = 0.0167$. Group A, upright sitting; Group B, conventional core exercise; Group C, combined.

DISCUSSION

In this trial, four weeks of upright sitting produced greater improvements in frontal-plane alignment of the head, shoulders and pelvis than conventional core exercise or the combined intervention, whereas conventional exercise produced greater improvement in knee alignment than upright sitting. Foot alignment improved in all three groups, with no evidence of a between-group difference. These findings suggest that the relative effects of the interventions varied across anatomical regions.

The regional pattern broadly corresponded to the demands of the prescribed interventions. Upright sitting required participants to maintain a symmetrical trunk and pelvic configuration without back support. Previous research has demonstrated that different upright sitting configurations alter spinal–pelvic curvature and trunk muscle activation [6]. Conversely, the conventional exercise programme included bridging, leg lifts and one-leg sliding, which repeatedly engaged the trunk and lower limbs. Electromyographic research confirms that rehabilitation exercises such as bridging recruit trunk, hip and thigh muscles [10]. These studies provide physiological context for the regional differences observed here, but they do not establish that engagement of a particular region causes improvement in its frontal-plane alignment. The correspondence between intervention demands and alignment changes should therefore be regarded as an interpretation of the present findings rather than a demonstrated mechanism.

Small frontal-plane asymmetries are common in healthy young adults. Ferreira et al. reported minor asymmetries of the head, shoulders, pelvis and other body segments in standing, suggesting that perfect symmetry is not the usual postural presentation [11]. Similarly, D'Amico et al. identified postural and spinal asymmetry as a common feature in asymptomatic young adults [12]. Trovato et al. provided digital postural reference data for healthy young adults, offering additional context for interpreting body-segment alignment in this population [9]. The non-zero baseline alignment scores in the present trial are therefore compatible with normal postural variation. In this asymptomatic population, the observed

changes are more appropriately described as reductions in measured asymmetry than as correction of an established pathology. Their clinical significance cannot be established from alignment changes alone.

The ordering of interventions for postural alignment differed from that observed for the muscular and respiratory outcomes of the same trial. The combined intervention was the strongest or joint-strongest performer for those outcomes, whereas upright sitting alone produced the greatest alignment improvement in three of the five regions assessed. This divergence suggests that improvements in muscular performance do not necessarily correspond to proportional improvements in segmental alignment. Wang et al. reported improvements in trunk muscle contractility and static postural control following both progressive postural control exercise and core stability exercise, without significant between-group differences [13]. However, their study assessed centre-of-pressure sway in participants with chronic low back pain rather than photographic segmental alignment in asymptomatic adults. It therefore provides contextual evidence rather than direct confirmation of the present findings. Postural alignment and muscular performance should be evaluated as distinct outcomes, and their relationship requires direct investigation. In the present analysis, these outcomes were not examined in relation to one another, preventing conclusions about whether muscular changes mediated alignment changes.

The combined intervention provided no additional advantage in frontal-plane alignment. For the shoulders and pelvis, improvement was smaller in the combined group than in the upright-sitting group. These findings indicate that combining the interventions did not produce an additive alignment benefit under the conditions of this trial. The present analysis does not establish why the combined intervention produced smaller improvements in these regions. Consequently, this pattern should be reported as an observed comparative finding without attributing it to an untested physiological mechanism.

Interpretation must also account for improvement in every region across all three groups. Although this pattern is compatible with beneficial effects of each intervention, within-group improvement alone cannot distinguish treatment effects from repeated-assessment influences or other sources of change. Regression toward the mean can contribute to apparent improvement in repeated measurements [14]. However, participants were selected for low core endurance rather than extreme alignment scores, so its contribution to the alignment findings remains uncertain. Familiarity with the photographic procedure is another possible explanation, although it was not assessed. The randomized between-group comparisons are therefore more informative for evaluating relative intervention effects, particularly when baseline values are appropriately accounted for [15]. Without an untreated comparison group, the extent to which the improvements shared by all three groups exceeded changes that would have occurred without intervention remains uncertain.

Finally, the absence of assessor blinding remains a limitation. Empirical evidence indicates that nonblinded assessment can produce more favourable estimates of intervention effects for outcomes involving assessor judgement [16]. The present findings did not show a uniform advantage for upright sitting: conventional exercise was superior at the knees, while foot alignment showed no evidence of a between-group difference. Nevertheless, this regional pattern cannot exclude outcome-specific assessor bias. The findings should therefore be interpreted cautiously and confirmed in studies using blinded outcome assessment.

LIMITATIONS

The absence of assessor blinding and operator-dependent landmark placement may have introduced assessment bias. Assessment was limited to frontal-plane alignment using an application with ordinal scores, unestablished responsiveness, and no established minimal clinically important difference, therefore, the magnitude and clinical relevance of changes remain uncertain. Findings apply to asymptomatic students aged 18–25 years with low core endurance, hence generalization of results to other groups is limited.

CONCLUSION

Four weeks of upright sitting improved frontal-plane alignment of the head, shoulders and pelvis more than conventional core exercise or the combination of the two, while conventional exercise improved knees alignment more than upright sitting. Improvement was regional rather than global and did not follow the ordering seen for muscular outcomes in the same trial, suggesting that postural alignment and trunk muscle strength are not interchangeable endpoints. Upright sitting, which requires no equipment and no supervised exercise time, appears the more effective of the two for alignment of the segments it directly holds. These findings are limited by the absence of assessor blinding and require confirmation in a trial with independent postural assessment.

CRediT authorship contribution statement

Varsha Huddar: Conceptualization, Methodology, Investigation, Data curation, Writing – original draft.

Sanjiv Kumar: Conceptualization, Supervision, Writing – review & editing.

Ashwini Patil: Supervision, Writing – review & editing." Please amend so that each statement reflects each author's actual contribution.

Declaration of competing interest

The authors declare the following financial interests which may be considered as potential competing interests: New Body Technologies waived the APECS subscription charges for a period of three months for the conduct of this study. The company had no role in the design of the study, in the collection, analysis or interpretation of data, in the writing of the report, or in the decision to submit the article for publication.

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Ethics approval and consent to participate

The study was approved by the Institutional Ethics Committee on 4 November 2024 (reference KAHER/EC/24-25/417). All participants provided written informed consent before enrolment.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Relationship to other publications

This manuscript reports a pre-specified secondary outcome of a randomized controlled trial registered under CTRI/2025/01/079014. The primary outcome and the remaining secondary outcomes are reported in companion papers derived from the same trial. This work forms part of the doctoral thesis of the first author.

REFERENCES

1. Moulin MS, Truelove S, Burke SM, Irwin JD. Sedentary time among undergraduate students: a systematic review. *J Am Coll Health*. 2021;69(3):237–44. doi:10.1080/07448481.2019.1661422.
2. Dzakpasu FQS, Carver A, Brakenridge CJ, Cicuttini F, Urquhart DM, Owen N, et al. Musculoskeletal pain and sedentary behaviour in occupational and non-occupational settings: a systematic review with meta-analysis. *Int J Behav Nutr Phys Act*. 2021;18(1):159. doi:10.1186/s12966-021-01191-y.
3. Kandasamy G, Almanasef M, Almeleebia T, Orayj K, Shorog E, Alshahrani AM, et al. Prevalence of musculoskeletal pain among undergraduate students. *Front Med*. 2024;11:1403267. doi:10.3389/fmed.2024.1403267.
4. O'Sullivan PB, Dankaerts W, Burnett AF, Farrell GT, Jefford E, Naylor CS, et al. Effect of different upright sitting postures on spinal-pelvic curvature and trunk muscle activation in a pain-free population. *Spine*. 2006;31(19):E707–12. doi:10.1097/01.brs.0000234735.98075.50.
5. Fujitani R, Jiroumaru T, Noguchi S, Michio W, Ohnishi H, Suzuki M, et al. Effect of low back pain on the muscles controlling the sitting posture. *J Phys Ther Sci*. 2021;33(3):295–8. doi:10.1589/jpts.33.295.
6. (O'Sullivan PB, Dankaerts W, Burnett AF, Farrell GT, Jefford E, Naylor CS, O'Sullivan KJ. Effect of different upright sitting postures on spinal-pelvic curvature and trunk muscle activation in a pain-free population. *Spine*. 2006 Sep 1;31(19):E707–12.)
7. Ribeiro DC, Milosavljevic S, Terry J, Abbott JH. Effectiveness of a lumbopelvic monitor and feedback device to change postural behaviour: the ELF cluster randomised controlled trial. *Occup Environ Med*. 2020;77(7):462–9. doi:10.1136/oemed-2019-106293.
8. Wang H, Fan Z, Liu X, Zheng J, Zhang S, Zhang S, et al. Effect of progressive postural control exercise versus core stability exercise in young adults with chronic low back pain: a randomized controlled trial. *Pain Ther*. 2023;12(1):293–308. doi:10.1007/s40122-022-00458-x.
9. Trovato B, Roggio F, Sortino M, Zanghi M, Petrigna L, Giuffrida R, et al. Postural evaluation in young healthy adults through a digital and reproducible method. *J Funct Morphol Kinesiol*. 2022;7(4):98. doi:10.3390/jfmk7040098.
10. Ekstrom RA, Donatelli RA, Carp KC. Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises. *J Orthop Sports Phys Ther*. 2007;37(12):754–62. doi:10.2519/jospt.2007.2471.
11. Ferreira EA, Duarte M, Maldonado EP, Bersanetti AA, Marques AP. Quantitative assessment of postural alignment in young adults based on photographs of anterior, posterior, and lateral views. *J Manipulative Physiol Ther*. 2011;34(6):371–80. doi:10.1016/j.jmpt.2011.05.018.
12. D'Amico M, Kinel E, Roncoletta P. Normative 3D opto-electronic stereo-photogrammetric posture and spine morphology data in young healthy adult population. *PLoS One*. 2017;12(6):e0179619. doi:10.1371/journal.pone.0179619.
13. Wang H, Fan Z, Liu X, Zheng J, Zhang S, Zhang S, et al. Effect of progressive postural control exercise versus core stability exercise in young adults with chronic low back pain: a randomized controlled trial. *Pain Ther*. 2023;12(1):293–308. doi:10.1007/s40122-022-00458-x.
14. Barnett AG, van der Pols JC, Dobson AJ. Regression to the mean: what it is and how to deal with it. *Int J Epidemiol*. 2005;34(1):215–20. doi:10.1093/ije/dyh299.
15. Vickers AJ, Altman DG. Statistics notes: analysing controlled trials with baseline and follow up measurements. *BMJ*. 2001;323(7321):1123–4. doi:10.1136/bmj.323.7321.1123.
16. Hróbjartsson A, Thomsen ASS, Emanuelsson F, Tendal B, Hilden J, Boutron I, et al. Observer bias in randomized clinical trials with measurement scale outcomes: a systematic review of trials with both blinded and nonblinded assessors. *CMAJ*. 2013;185(4):E201–11. doi:10.1503/cmaj.120744.