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THE EFFECT OF A PROGRESSIVE CORE EXERCISE PROGRAM ON BALANCE, POSTURE, AND FUNCTIONAL FITNESS IN SEDENTARY FEMALE UNIVERSITY STUDENTS: A RANDOMIZED CONTROLLED STUDY

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Abstract

Introduction. The aim of this study was to investigate the effects of an eight-week progressive core exercise program on balance, posture, and functional fitness in sedentary female university students. **Material and Methods.** Forty sedentary female university students aged 18–25 years were randomized into a core exercise group (CEG, $n = 20$) and a control group (CG, $n = 20$). CEG performed a progressive core exercise program 3 days a week for 8 weeks (40 min/session in weeks 1–4; 45 min/session in weeks 5–8). Outcome measures included posture (New York Posture Analysis), static balance (Flamingo Balance Test), dynamic balance (Y-Balance Test), muscular endurance (plank, side plank, sit-ups, V-ups), flexibility (sit-and-reach), and muscular strength (handgrip, back and leg dynamometry). Effect sizes were calculated using the Morris (2008) approach. **Results.** Statistically significant improvements and large effect sizes were observed in muscular endurance, flexibility, static balance, and postural alignment in CEG ($p < 0.05$; Morris $d = 0.48$ – 1.70). Within-group improvements were also noted in muscular strength parameters; however, between-group differences did not reach statistical significance ($p > 0.05$). No significant changes were detected in CG. **Conclusions.** An eight-week progressive core exercise program significantly improved muscular endurance, flexibility, static balance, and postural alignment in sedentary female university students. Core exercise represents a feasible, low-cost, and effective intervention for this population.

Keywords: core exercise, functional fitness, balance, posture, sedentary lifestyle, female university students

Introduction

The decline in physical activity levels globally remains a significant public health concern, particularly among young adults. According to the World Health Organization's 2022 global physical activity report, more than a quarter of adults worldwide exhibit insufficient physical activity [1]. This situation is particularly pronounced among university students; a systematic review and meta-analysis conducted by Castro et al. found that university students spend an average of 9.82 hours a day being sedentary [2].

A similar situation exists in Türkiye. Öner et al. reported that sedentary lifestyle among adults in Türkiye increased from 37.3% to 39.9% between 2014 and 2023, and that men were 1.91 times more active than women [3]. Edelmann et al. reported that insufficient physical activity is significantly prevalent among university students, with female students constituting the highest risk group [4]. Kljajević et al. revealed that physical fitness levels of university students are alarmingly low on a global scale [5].

The negative effects of a sedentary lifestyle on the musculoskeletal system are becoming increasingly better understood. Prolonged immobility leads to decreased muscle strength, postural disorders, reduced balance capacity, and overall loss of functional performance. Core muscles comprise the essential muscle groups encompassing the abdomen, lower back, hips, and pelvic region, and are responsible for overall body stabiliza-

tion. The role of these muscles in postural control, balance, and force transmission has been extensively documented [6].

Rodríguez-Perea et al. reported that core training led to significant improvements in balance with a large effect size ($SMD = 1.17$) [7]. Turgut et al. demonstrated that eight weeks of core stabilization exercises significantly improved trunk muscle strength, upper extremity performance, and balance in female wrestlers [8]. Panhale et al. reported that core stabilization exercises significantly improved balance and functional performance [9]. Sedentary female university students represent a particularly underexplored subgroup in exercise science research. Although physical inactivity and sedentary behaviour are well-established risk factors for poor health outcomes across adult populations [10], studies specifically targeting female university students within a multidimensional fitness framework – combining balance, posture, and functional fitness – remain scarce [11]. Guo et al. (2022) demonstrated that inactive female university students showed significantly lower cardiorespiratory fitness and overall physical fitness scores compared to their active peers, underscoring the need for targeted, evidence-based exercise interventions for this population. Complementing these findings, Almurdi (2024) reported that postural balance was measurably reduced among female university students with higher body mass indices, while noting that the multidimensional fitness dimensions of this group remain insufficiently examined.

Randomized controlled trials evaluating balance, posture, and multidimensional functional fitness parameters together in sedentary female university students are limited in the literature [12, 13]. This study aimed to examine the effects of an eight-week progressive core exercise program on balance, postural alignment, and functional fitness in sedentary female university students.

Based on the existing literature, it was hypothesised that: (H1) an eight-week progressive core exercise program would significantly improve muscular endurance and flexibility in sedentary female university students; (H2) static balance and postural alignment would show significant improvements in favour of CEG; and (H3) dynamic balance and muscular strength would demonstrate within-group improvements, though between-group differences were expected to be smaller given the indirect effects of core training on these parameters.

Material and Methods

Study Design

This study was conducted using a parallel randomized controlled experimental design with two-group pretest-posttest measurements. Participants were randomly assigned to either the core exercise group (CEG) or the control group (CG) using a sealed envelope method. The randomization process was performed using a computer-generated random number sequence with opaque, sequentially numbered envelopes. The study was conducted between September and October 2025 in the indoor sports hall of the Faculty of Sports Sciences at Uşak University, from 10:00 to 12:00. The study was carried out and reported in accordance with the CONSORT guidelines [14].

Ethical Approval

Prior to starting this study, ethical approval was obtained from the Uşak University Non-Interventional Clinical Research Ethics Committee (Decision No: 659-659-07, Date: May 15th, 2025). All procedures were conducted in accordance with the ethical principles of the World Medical Association's Helsinki Declaration [15]. Written informed consent was obtained from all participants.

Research Group

Inclusion criteria: (1) female gender, (2) 18-25 years of age, (3) no regular exercise program for at least six months, (4) BMI 18.5-29.9 kg/m².

Exclusion criteria: (1) illness preventing exercise participation, (2) ongoing medication use, (3) pregnancy, (4) simultaneous participation in another exercise program.

Sample size was determined using an a priori power analysis with G*Power (version 3.1.9.7). Based on large effect sizes ($d \geq$

1.00; SMD = 1.32) reported in the literature [7], calculations with $\alpha = 0.05$ and 80% power showed a minimum of 34 participants ($n = 17$ per group) were sufficient. Accounting for potential dropouts, sample size was planned as 40 participants ($n = 20$ per group). The study was completed without any losses.

Intervention Protocol

Participants were asked to record any missed sessions and report reasons for absence; no compensatory sessions were provided. Adherence rate across all 24 sessions was 100%, with no missed sessions reported.

CEG applied a progressive core exercise program under expert supervision for eight weeks, three days a week (Monday, Wednesday, Friday), totalling 24 sessions. Each session consisted of a warm-up (10 min), main exercise phase (25 min in weeks 1-4; 30 min in weeks 5-8), and cool-down (5 min), with total session durations of 40 and 45 minutes, respectively. During weeks 1-4 and 6-7, exercises were performed at low intensity (3 sets $\times$ 10-12 repetitions; isometric: 20-30 sec; rest: 45-60 sec). During weeks 5-8 and 7-8, exercises were performed at increasing intensity (3 sets $\times$ 12-15 repetitions; isometric: 30-45 sec). Details are provided in Table 1. Participants in both groups were verbally instructed not to alter their daily physical activity routines or begin an additional exercise program. Adherence was monitored via self-report every two weeks. CG continued their usual daily life.

Measurement Tools

Anthropometric measurements: height was measured with a Harpenden stadiometer (± 0.1 cm) and body weight with an electronic scale (± 0.1 kg). BMI = weight/height² (kg/m²).

Muscular endurance: plank test (maximum time in prone position with forearm support, sec), side plank test (right and left separately, sec), sit-up test (maximum repetitions in 60 sec), and V-ups test (maximum repetitions in 60 sec) were performed [16, 17]. Two attempts were given for each test, and the best value was recorded.

Flexibility: evaluated with the sit-and-reach test. The best value from two trials was recorded in cm [18].

Muscle strength: handgrip strength was measured with a hand dynamometer using three trials per hand; the highest value was recorded. Back and leg strength was measured with a back-leg dynamometer using the best value from two trials [18].

Balance: static balance was evaluated with the Flamingo Balance Test (60 sec on a 3 $\times$ 4 $\times$ 50 cm balance beam; lower error count indicates better balance). Dynamic balance was evaluated with the Y-Balance Test (YBT). Reach distances in the anterior (ANT), posterolateral (PL), and posteromedial (PM) directions

Table 1. Summary of the eight-week progressive core exercise program.

Week	Main Phase	Exercises Performed (Days 1, 2, and 3)	Set $\times$ Repetitions / Duration
1-4	25 min	Day 1: Plank, Dead Bug, Glute Bridge, Reverse Crunch, Superman, Hollow Body Hold Day 2: Side Plank, Bird-Dog, Russian Twist, Leg Raises, Bicycle Crunch, Pallof Press Day 3: Plank Shoulder Tap, Mountain Climbers, Crunch, Bear Crawl Hold, V-sit Hold, Glute Bridge March	3 sets $\times$ 10-12 rep Isometric: 20-30 sec Recovery: 45-60 sec
5-8	30 min	All previous exercises supplemented with Hip Thrust (Day 1), Side Plank Hip Dip (Day 2), and Inchworm (Day 3).	3 sets $\times$ 12-15 rep Isometric: 30-45 sec Recovery: 45-60 sec

Note: min: minute; sec: second; rep: repetitions.

were measured; Composite Score (CS) = $[(ANT + PL + PM) / (\text{Leg length} \times 3)] \times 100$ [19].

Posture assessment: New York Posture Analysis Method (NPAY) was used. This method evaluates 13 anatomical items: total score ranges from 13 to 65, with higher scores indicating better postural alignment [20]. All assessments were performed by the same licensed physiotherapist, blinded to group assignment.

Statistical Analysis

Data were analysed using Python (version 3.12) and the SciPy library (version 1.11). Normal distribution was assessed with the Shapiro-Wilk test. Independent-sample t-test and paired-sample t-test were used for normally distributed variables; Mann-Whitney U test and Wilcoxon signed-rank test were applied for non-normal distributions. Effect size was calculated using the Morris (2008) approach: $d = (\Delta CEG - \Delta CG) / SD_{\text{pre-pooled}}$ [21]. Effect size classification followed Cohen (1988) criteria: 0.20-0.49 small, 0.50-0.79 medium, ≥ 0.80 large [22]. Compared to the targeted effect size ($d \geq 1.00$) in the G*Power analysis, Morris d values ranged from 0.15 to 1.70. Parameters reaching between-group significance showed Morris $d = 0.48$ -1.70, indicating the targeted effect size was largely achieved. Small effect sizes in muscular strength parameters ($d = 0.15$ -0.39) indicated limited statistical power for these variables. Statistical significance was set at $p < 0.05$.

Results

All 40 participants completed the eight-week intervention. There were no statistically significant differences between CEG and CG at baseline in age, height, body weight, or BMI ($p > 0.05$). Demographic characteristics are presented in Table 2.

Table 2. Demographic characteristics of the research group (t-test).

Variable	CEG (n = 20) Mean $\pm$ SD	CG (n = 20) Mean $\pm$ SD	p
Age (years)	20.90 $\pm$ 1.65	21.35 $\pm$ 1.46	0.367
Height (cm)	165.05 $\pm$ 5.19	164.75 $\pm$ 4.82	0.851
Body weight (kg)	58.60 $\pm$ 9.05	61.20 $\pm$ 7.54	0.330
BMI (kg/m ²)	21.48 $\pm$ 3.01	22.55 $\pm$ 2.61	0.240

Note: SD: Standard Deviation; CEG: Core Exercise Group; CG: Control Group; BMI: Body Mass Index.

Muscular Endurance

CEG showed statistically significant improvements in all muscular endurance parameters ($p < 0.001$). Plank duration increased from 49.75 $\pm$ 21.51 to 72.15 $\pm$ 29.53 sec (Morris $d = 1.11$); side plank right from 24.75 $\pm$ 12.88 to 41.55 $\pm$ 15.65 sec ($d = 1.19$); side plank left from 24.20 $\pm$ 11.33 to 38.35 $\pm$ 13.95 sec ($d = 1.18$). Sit-up repetitions increased from 23.05 $\pm$ 6.02 to 34.30 $\pm$ 6.02 ($d = 1.70$); V-ups from 16.05 $\pm$ 5.81 to 25.00 $\pm$ 5.51 ($d = 1.69$). All changes indicated large effect sizes. No significant changes were observed in CG ($p > 0.05$). CEG showed significant superiority in all parameters in the between-group post-test comparison ($p \leq 0.015$).

Flexibility

The sit-and-reach test value increased significantly from 22.30 $\pm$ 3.06 to 23.80 $\pm$ 3.14 cm in CEG ($p < 0.001$; Morris $d = 0.48$). No significant change was observed in CG ($p = 0.527$).

A significant between-group post-test difference was found in favour of CEG ($p = 0.044$).

Muscle Strength

In CEG, significant within-group increases were observed for handgrip right (21.70 $\rightarrow$ 22.70 kg; $p = 0.014$; $d = 0.15$), handgrip left (18.60 $\rightarrow$ 19.65 kg; $p = 0.015$; $d = 0.39$), back strength (52.70 $\rightarrow$ 54.65 kg; $p < 0.001$; $d = 0.26$), and leg strength (60.85 $\rightarrow$ 62.05 kg; $p = 0.011$; $d = 0.20$). However, no between-group post-test significance was reached (handgrip right: $p = 0.066$; handgrip left: $p = 0.156$; back strength: $p = 0.393$; leg strength: $p = 0.358$).

Balance

In the Flamingo Balance Test, CEG showed significant reductions in error count for the right foot (8.10 $\pm$ 2.13 $\rightarrow$ 5.65 $\pm$ 1.79; $p < 0.001$; Morris $d = 1.00$) and left foot (10.40 $\pm$ 2.23 $\rightarrow$ 7.00 $\pm$ 1.89; $p < 0.001$; $d = 1.14$). Between-group post-test differences were significant for both ($p < 0.001$). YBT left composite score increased from 77.08 $\pm$ 9.54% to 79.96 $\pm$ 9.08% ($p < 0.001$; $d = 0.39$); YBT right from 76.26 $\pm$ 10.19% to 80.17 $\pm$ 10.40% ($p < 0.001$; $d = 0.40$). However, between-group post-test differences did not reach significance (right: $p = 0.237$; left: $p = 0.171$). No significant changes were observed in CG.

Postural Alignment

The New York Posture Analysis score increased significantly from 51.40 $\pm$ 3.70 to 55.40 $\pm$ 4.03 in CEG ($p < 0.001$; Morris $d = 0.88$). No significant change was observed in CG ($p = 0.227$). The between-group post-test difference was significant ($p = 0.009$).

All results are summarized in Table 3.

Discussion

This study demonstrated that an eight-week progressive core exercise program statistically and practically improved muscular endurance, flexibility, static balance, and postural alignment in sedentary female university students. In contrast, while within-group increases were observed in muscular strength parameters, these changes did not reach statistical significance in between-group comparisons.

Muscular Endurance

Plank time increased by 45%, sit-up performance by 49%, and V-up repetitions by 56%. Morris d values (1.11-1.70) indicated large effect sizes across all parameters. Turgut et al. reported that eight weeks of core stabilization significantly improved core muscular endurance in female wrestlers [8]. Granacher et al. showed that core strength training improved plank performance in adolescents with a large effect size [23]. A meta-analysis by Rodríguez-Perea et al. found large effects of core training on endurance (SMD = 1.32) [7]. The large effect sizes observed may be explained by the low baseline level of sedentary individuals and their neuromuscular adaptation response to progressive loading.

Flexibility

Flexibility assessed by the sit-and-reach test increased significantly in CEG ($p < 0.001$; Morris $d = 0.48$), corresponding to a small effect size. The between-group post-test difference was borderline significant ($p = 0.044$). The indirect effect of core exercises on flexibility may be associated with increased pelvic-lumbar mobility and relaxation of peri-muscular connective

Table 3. Statistical comparisons of pre-test and post-test results of the research group.

Variable	CEG Pre X ± SD	CEG Post X ± SD	p (CEG)	CG Pre X ± SD	CG Post X ± SD	p (CG)	Between Groups (p)	Morris d
MUSCULAR ENDURANCE								
Plank (sec)	49.75 ± 21.51	72.15 ± 29.53	<0.001***	51.60 ± 18.21	51.95 ± 19.33	0.661 ns	0.015*	1.11
Side Plank Right (sec)	24.75 ± 12.88	41.55 ± 15.65	<0.001***	27.35 ± 10.60	28.05 ± 9.03	0.349 ns	0.002**	1.19
Side Plank Left (sec)	24.20 ± 11.33	38.35 ± 13.95	<0.001***	26.10 ± 12.95	25.95 ± 11.62	0.802 ns	0.004**	1.18
Sit-up (rep)	23.05 ± 6.02	34.30 ± 6.02	<0.001***	23.60 ± 6.92	23.80 ± 6.69	0.677 ns	<0.001***	1.70
V-ups (rep)	16.05 ± 5.81	25.00 ± 5.51	<0.001***	16.70 ± 4.97	16.50 ± 4.62	0.447 ns	<0.001***	1.69
FLEXIBILITY								
Sit and Reach (cm)	22.30 ± 3.06	23.80 ± 3.14	<0.001***	21.70 ± 2.54	21.85 ± 2.76	0.527 ns	0.044*	0.48
MUSCLE STRENGTH								
Grip Right (kg)	21.70 ± 2.85	22.70 ± 3.33	0.014*	20.20 ± 3.61	20.70 ± 3.34	0.335 ns	0.066 ns†	0.15
Grip Left (kg)	18.60 ± 2.41	19.65 ± 2.58	0.015*	18.40 ± 3.60	18.25 ± 3.48	0.605 ns	0.156 ns†	0.39
Back Strength (kg)	52.70 ± 8.30	54.65 ± 8.27	<0.001***	52.65 ± 7.69	52.50 ± 7.44	0.745 ns	0.393 ns†	0.26
Leg Strength (kg)	60.85 ± 8.20	62.05 ± 8.51	0.011*	59.95 ± 8.28	59.50 ± 8.82	0.384 ns	0.358 ns†	0.20
BALANCE								
FBT Right (score)↓	8.10 ± 2.13	5.65 ± 1.79	<0.001***	8.45 ± 2.37	8.25 ± 2.00	0.259 ns	<0.001***	1.00
FBT Left (score)↓	10.40 ± 2.23	7.00 ± 1.89	<0.001***	10.85 ± 3.15	10.55 ± 2.87	0.141 ns	<0.001***	1.14
YBT Right CS (%)	76.26 ± 10.19	80.17 ± 10.40	<0.001***	76.42 ± 9.28	76.45 ± 9.13	0.954 ns	0.237 ns†	0.40
YBT Left CS (%)	77.08 ± 9.54	79.96 ± 9.08	<0.001***	76.77 ± 7.61	76.31 ± 7.38	0.374 ns	0.171 ns†	0.39
POSTURE								
NYP (points)	51.40 ± 3.70	55.40±4.03	<0.001***	51.80 ± 4.02	52.40 ± 4.31	0.227 ns	0.009**	0.88

*** – $p < 0.001$; ** – $p < 0.01$; * – $p < 0.05$; ns: not significant; d: Morris (2008) effect size; CEG: Core Exercise Group; CG: Control Group; CS: Composite Score; FBT: Flamingo Balance Test (↓ lower value indicates better balance); YBT: Y-Balance Test; NYP: New York Posture Analysis. † Intra-group CEG change was significant, but between-group post-test difference did not exceed statistical significance threshold ($p > 0.05$).

tissue. Tsartsapakis et al. highlighted the positive effects of eight weeks of core training on neuromuscular control and muscle tone balance [24].

Muscle Strength

CEG showed significant within-group increases in hand-grip, back, and leg strength; however, effect sizes remained small ($d = 0.15$ - 0.39) and no between-group significance was reached. This may be explained by core exercises primarily targeting trunk stabilization without direct loading of peripheral muscle groups [7]. Additionally, high individual variability in back and leg strength ($SD \approx 8$ kg) combined with the small sample size ($n = 20$ /group) may have limited the detection of between-group differences. Significant within-group improvements suggest that the strength-building potential of core exercises may become more pronounced with longer interventions or combined specific resistance training.

Balance

The Flamingo Balance Test yielded large effect sizes (Morris $d = 1.00$ - 1.14) and significant between-group differences. Despite significant within-group YBT composite score increases in CEG ($p < 0.001$), between-group post-test differences did not reach significance (right: $p = 0.237$; left: $p = 0.171$), with small effect sizes ($d = 0.39$ - 0.40). Coordinated activation of core muscles accelerates protective responses against balance disruptions and reduces postural oscillation [6]. Panhale et al. also supported significant effects of core stabilization on balance [9]. The lack of between-group significance in YBT may be related to the

intervention similarly improving both extremities and individual variations in asymmetry.

Postural Alignment

A significant increase in New York Posture Analysis score was observed in CEG after eight weeks (Morris $d = 0.88$). This finding indicates that strengthening core muscles improves postural alignment by increasing spinal stability through the transversus abdominis, multifidus, and erector spinae muscles. Muscle imbalances and postural disorders caused by prolonged sitting in sedentary individuals can be corrected with core exercises [5].

Conclusions

An eight-week progressive core exercise program significantly improved muscular endurance, flexibility, static balance, and postural alignment in sedentary female university students, with significant within-group improvements also observed in dynamic balance and muscular strength parameters. These findings confirm hypotheses H1 and H2, while H3 was partially supported given the within-group but not between-group significance in strength and dynamic balance.

Core exercises represent a low-cost, accessible, and effective intervention for improving multiple components of physical fitness in this population. For more pronounced improvements in muscular strength, supplementing core exercises with specific resistance training is recommended.

Integrating this program into university curricula as an elective physical education course, scheduling short on-campus exercise breaks, or incorporating it into wellness programs can be considered low-cost and scalable strategies to improve physical fitness in sedentary students.

Several limitations of this study should be acknowledged. The sample size was relatively small ($n = 40$; $n = 20$ per group), which, although supported by a priori power analysis, limits generalizability. The sample comprised exclusively sedentary female university students aged 18-25, restricting the applicability of findings to other populations such as males, older adults, or athletes. The intervention period of eight weeks may be insufficient for detecting significant between-group differences in muscular strength. Daily physical activity outside the intervention was monitored only by self-report every two weeks, which may introduce recall bias. Finally, the absence of long-term follow-up measurements precludes conclusions about the sustainability of observed improvements.

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