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Molecular & Cellular Biomechanics 2024, 21(2), 376.
https://doi.org/10.62617/mcb.v21i2.376

Article

Addressing mental health challenges in college students: A biomechanical approach to mitigating stress and cognitive load through physical intervention strategies

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CITATION

Wang C. Addressing mental health challenges in college students: A biomechanical approach to mitigating stress and cognitive load through physical intervention strategies. Molecular & Cellular Biomechanics. 2024; 21(2): 376. https://doi.org/10.62617/mcb.v21i2.376

ARTICLE INFO

Received: 15 September 2024
Accepted: 24 September 2024
Available online: 5 November 2024

Abstract: The main objective of this investigation is to find out how biomechanical actions, such as physical activity programs, balanced adjustments, and mindfulness-based posture correction, are successful at reducing Cognitive Load (CL) and levels of stress among college students. Mechanical adjustments decreased stress, physical activity reduced CL, and mindfulness-based posture correction improved Mental Health (MH), according to a long-term experiment with 28 students from four distinct educational fields. Investigators examined students' stress, CL, and BH levels monthly. The outcome results dealt with all three predictions. A student's Perceived Stress Scale (PSS) score dropped from 24.66 to 18.10 (mean difference = 6.56, $t = 4.82$, $p = 0.0001$) after experiencing practical changes, demonstrating a significant decrease in stress levels. Following the exercise support, CL, as determined by the NASA Task Load Index (NASA-TLX), dropped from 65.38 to 54.23 (mean difference = 11.15, $t = 5.29$, $p = 0.00005$). Ratings for BH increased significantly after exercising mindfulness-based posture correction (from 78.63 to 85.13; mean difference = −6.50, $t = -4.92$, $p = 0.00007$). The median variation in PF (VO2 Max) went from 40.46 to 45.11 ($t = -3.78$, $p = 0.0012$), and the difference in value was −4.65.

Keywords: biomechanical health; biomechanical interventions; cognitive load; posture correction; physical fitness; mental and physical health; machine learning

1. Introduction

College students experience an increasing quantity of Mental Health (MH) issues because of the increased Cognitive Load (CL) and stress imposed by academic demands, expectations from society, and individual responsibilities [1]. Mental health (MH) and Physical Health (PH), as well as academic performance, can be impacted by these stresses [2]. There is a growing demand for physical measures that reduce stress and enhance cognitive function, in addition to the standard MH support that emphasizes counselling and psychological interventions [3]. This research aims to determine whether college students can alleviate their CL and stress by biomechanical correction, involving factors like mindfulness training, structured exercise, and ergonomic modifications [4–8]. Workstations that are wholly or partially not correctly designed may strain both PH and MH and psychological strain, making psychology a vital part of functional and comfortable work environment design [9–12]. Reduced physical strain and stress levels can be addressed for students through ergonomic approaches that maximize their physical environment [13–16].

Physical activity also has gained notoriety as an effective tool for stress management and cognitive development [17]. Student training regimens focusing on biomechanical alignment and functional movement can alleviate CL, improve focus, and strengthen MH [18,19]. Along with biomechanical interventions that boost alignment and posture, mindfulness practices can help with stress management and MH [20–25]. With the support of this integrated intervention approach, students may improve their PH and MH states, permitting them to be successful in the learning environment. The hybrid intervention approach provides a complete approach for CL and stress management.

The present paper investigates the possible use of biomechanical interventions for reducing stress and CL in the educational setting, including ergonomic changes, physical activity programs developed with biomechanical in mind, and mindfulness-based posture correction. Two colleges were involved in the anticipated long-term study, which included 28 participants. Constant fidelity to the intervention model for the study was tracked by periodic evaluations of stress, CL, and Biomechanical Health (BH). The main objective of the present research is to explore whether this intervention model might enhance standard MH interventions. The study's primary objective is to discover long-term solutions to the MH and PH problems that college students experience to have a superior quality of life (QoL), academic achievement, and general health.

The study presents the following hypothesis:

a) Ergonomic adjustments will reduce stress (Hypothesis 1),
b) Physical exercise will decrease CL (Hypothesis 2), and
c) Posture correction through mindfulness will improve overall MH (Hypothesis 3).

Following is the framework of the article: Section 2 presents a summary of the approach used, Section 3 presents a discussion of the results, and Section 4 includes a conclusion to the research.

2. Methodology

A. Students Selection Criteria

The following eligibility requirements were developed for the selection of participants in order to ensure the accuracy and adaptability of the results of the research project:

1) Age: The study included students aged 18–45, a generally active age group less likely to experience mobility problems or cognitive failure.
2) Health Status: Students must be healthy and free from acute or chronic musculoskeletal conditions that could mark physical performance or distort biomechanical measurements.
3) Cognitive Load Experience: The study targets individuals experiencing moderate to high cognitive load or stress levels, as measured by the Perceived Stress Scale or a validated stress inventory, ensuring the relevance of stress-reducing interventions.
4) Physical Activity Level: Students were advised to engage in moderate physical activity for at least 2–3 days per week to ensure comfortable biomechanical interventions without risk of injury or fatigue.

B. Factors of Student Participants

A study involved 28 college students from two universities, selected across four academic disciplines. The participants were aged 18–25, with 11 Females and 17

Males. The ethnic diversity was diverse, with 10 Caucasian, 6 Hispanic, 5 Asian, 4 African American, and 3 from other experiences. Campus notices, flyers, and digital notifications made selections. Students were enrolled full-time and physically capable of participating. Each student provided informed consent and provided informed consent. Ethical approval was attained from the university's Institutional Review Board (IRB).

C. Experimental Design

The intervention involved ergonomic optimization, biomechanically personalized exercise programs, and mindfulness sessions. Students' workplaces were assessed for optimal posture and strain reduction. Adjustable furniture was provided for each student's body dimensions. The exercise model, conducted twice weekly, focused on biomechanical alignment and functional movement, including strength, flexibility, and balance exercises, to enhance overall Physical Fitness (PF) and reduce mental stress. Weekly mindfulness sessions were also conducted to improve biomechanical mindfulness through guided techniques. Data collection included baseline stress levels, CL, and academic performance measurements, followed by monthly assessments.

D. Equipment Used

For the ergonomic setup, the workstations with Herman Miller Aeron chairs (Remastered version) were provided for their comfort. The height-adjustable desks were provided by VariDesk ProDesk 60 Electrics (2020 model). For exercises, the cardiovascular workouts were done using Life Fitness Club Series+ Treadmills (Model CS-T5) and Precor EFX 222 Ellipticals. Resistance training utilized TheraBand Non-Latex Resistance Bands (Set of 5 strengths, 2021 edition) and Rogue Fitness Echo Bumper Plates (2021 set). For yoga and flexibility sessions, Manduka Pro Yoga Mats (71-inch, Midnight edition) were used. The biomechanical movement was captured using Vicon Motion Capture Systems (Vantage V16 cameras, 2021 release), which includes ultra-high-resolution cameras. Pressure distribution during various activities was assessed with Tekscan FlexiForce Pressure Mats (Model A401, 2022 edition). Continuous physiological data collection was carried out using Garmin Vivosmart 4 Activity Trackers. All data collected from these devices were analyzed using MATLAB (R2021a) and Visual3D (Version 6.01.03).

E. Guidelines for Test

Initially, the eligible participants were screened based on the study's inclusion criteria, and they were enrolled in the study and provided informed consent. Baseline stress levels, CL, and BH data were collected using initial questionnaires and biomechanical assessments. The intervention phase began with personalized ergonomic adjustments during the first two weeks. In weeks three and four, certified fitness instructors introduced and monitored the exercise program. By weeks five and six, mindfulness and biomechanical awareness sessions were integrated to improve body awareness and reduce stress through techniques taught by trained mindfulness instructors. Monthly assessments were done to analyze stress levels, CL, and BH changes. Adjustments to the interventions were made based on the monthly feedback to optimize the outcomes. At the end of the academic year, a comprehensive final evaluation was conducted. The data from these final assessments were compared with those of the control group, which had followed the same timeline without participating in the interventions. The following **Table 1** illustrates the study schedule and the equipment used.

Table 1. Intervention study stage with equipment details.

Stage	Activities/Equipment used	Timeline
1. Participant Screening and Enrollment	1) Screen participants based on inclusion criteria. 2) Enroll participants and obtain informed consent. 3) Collect baseline stress, CL, and BH data using standardized questionnaires and biomechanical assessments.	Weeks 1–2
2. Ergonomic Adjustments	1) Provide personalized ergonomic setups: 2) Herman Miller Aeron chairs. 3) VariDesk ProDesk 60 Electric desks. 4) Optimize setups based on biomechanical assessments using Vicon Motion Capture Systems.	Weeks 1–2
3. Exercise Regimen	1) Introduce biomechanically tailored exercise regimen: 2) Life Fitness treadmills. 3) Precor ellipticals. 4) Rogue Fitness weights. 5) TheraBand resistance bands. 6) Conduct sessions led by certified fitness instructors.	Weeks 3–4
4. Mindfulness and Biomechanical Awareness	1) Integrate mindfulness and biomechanical awareness sessions. 2) Teach stress reduction and body awareness techniques through trained mindfulness instructors.	Weeks 5–6
5. Monthly Assessments	1) Evaluate changes in stress, CL, and BH. 2) Use subjective questionnaires and objective measures (Tekscan Pressure Mats and Garmin Vivosmart 4 trackers). 3) Make adjustments to interventions based on feedback.	Monthly
6. Final Evaluation	1) Conduct comprehensive final assessments to determine the long-term effects of interventions. 2) Compare results with those from the control group. 3) Perform data analysis using MATLAB and Visual3D software.	End of Academic Year

F. Measures and Variables

Outcome Variables include measures that capture changes in participants' stress levels, CL, and BH. Stress is assessed using the Perceived Stress Scale (PSS). CL is measured with the NASA Task Load Index (NASA-TLX). Additionally, BH outcomes, such as postural alignment and movement efficiency, are captured through the Vicon Motion Capture System and Tekscan FlexiForce Pressure Mats. PF is evaluated through cardiovascular, muscular, and flexibility assessments, while subjective well-being is measured using the WHO-5 Well-Being Index. The independent variables in this study include the ergonomic adjustments made to participants' workstations, a biomechanically tailored exercise program, and mindfulness sessions focusing on biomechanical awareness. Several covariates are included to control for factors that might influence the outcomes [26–30]. These include age, gender, academic discipline, baseline PF, and pre-existing stress levels [31–34]. The following **Table 2** presents the measures and variables used in this study.

Table 2. Categorization of Measures and Variables.

Hypothesis	Outcome Variables	Independent Variables	Covariates
H1: Effect of Ergonomic Adjustments on Stress Reduction	1) Stress Levels: Measured by Perceived Stress Scale (PSS). 2) BH: Postural alignment and pressure distribution measured using Vicon Motion Capture and Tekscan Pressure Mats.	Ergonomic Adjustments: Personalized workstations (chairs, desks).	1) Age: Influence of age on the effects of ergonomic adjustments. 2) Gender: Differences in ergonomic needs and stress response. 3) Pre-existing Stress Levels: Initial stress may affect the outcomes. 4) Academic Discipline: Different ergonomic demands are present in various disciplines.
H2: Impact of Physical Exercise on CL	1) CL: Measured using NASA Task Load Index (NASA-TLX). 2) PF: Cardiovascular, strength, and flexibility assessments.	Exercise Regimen: Biomechanically tailored physical exercise program.	1) Age: Impact of fitness levels and exercise response across age groups. 2) Gender: Gender differences in fitness response. 3) Baseline PF: Pre-existing fitness influences exercise impact on CL.
H3: Role of Mindfulness and Biomechanical Awareness in MH	1) MH: Measured using WHO-5 Well-Being Index. 2) BH: Assessed by postural alignment and movement efficiency.	Mindfulness Sessions: Focus on biomechanical awareness and stress reduction.	1) Gender: Influence on stress management and body awareness. 2) Academic Discipline: Variations in mental load between disciplines. 3) Pre-existing Stress Levels: Initial stress may influence mindfulness effectiveness.

3. Analysis

3.1. Descriptive statistics

The descriptive statistics in **Table 3** and **Figure 1** display the changes in stress, CL, BH, and PF from baseline to post-intervention. For Hypothesis 1, the Baseline stress (PSS Score) had a mean of 24.66 (SD = 5.16), with scores ranging from 14 to 36. After the intervention, the mean stress score decreased to 18.10 (SD = 4.84), with scores between 8 and 28 confirming reduced stress after ergonomic adjustments. For Hypothesis 2 (Impact of Physical Exercise on CL), Baseline CL (NASA-TLX Score) had a mean of 65.38 (SD = 8.58), with a range of 49 to 81, which reduced to 54.23 (SD = 7.61) post-intervention, with scores ranging from 39 to 71 supporting the hypothesis that exercise lowers CL. Hypothesis 3 (Posture Correction and Well-being) is supported by an increase in BH (Posture Score); the mean score at baseline was 78.63 (SD = 6.42), ranging from 64 to 90, and improved to 85.13 (SD = 5.79) after the intervention, with scores between 69 and 96. PF (VO2 Max) had a baseline mean of 40.46 (SD = 5.01), with a range of 31 to 51, and increased to 45.11 (SD = 4.59) post-intervention, with scores between 34 and 54.

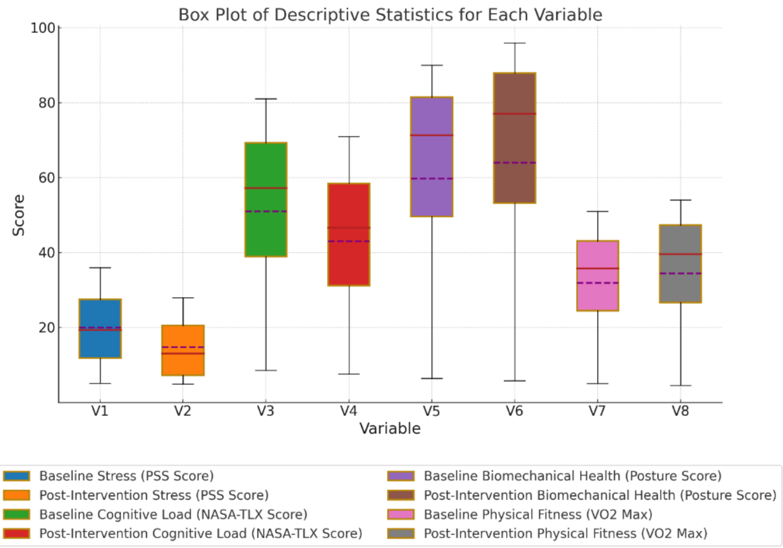

Figure 1. Descriptive statistics for each variable.

Table 3. Mean, Std. Dev of the variables.

Variable	Mean	Standard Deviation (SD)	Minimum	Maximum	*N* (Participants)
Baseline Stress (PSS Score)	24.66	5.16	14	36	28
Post-Intervention Stress (PSS Score)	18.10	4.84	8	28	28
Baseline CL (NASA-TLX Score)	65.38	8.58	49	81	28
Post-Intervention CL (NASA-TLX Score)	54.23	7.61	39	71	28
Baseline BH (Posture Score)	78.63	6.42	64	90	28
Post-Intervention BH (Posture Score)	85.13	5.79	69	96	28
Baseline PF (VO2 Max)	40.46	5.01	31	51	28
Post-Intervention PF (VO2 Max)	45.11	4.59	34	54	28

3.2. Pre-post comparison

The Pre-Post Comparison (Paired t-tests/Wilcoxon Signed-Rank Test) results were listed in **Table 4** and **Figure 2**, illustrating significant improvements across all variables. For stress (PSS Score), the mean dropped from 24.66 to 18.10 (mean difference = 6.56, $t = 4.82$, $p = 0.00010$), supporting Hypothesis 1. CL (NASA-TLX Score) decreased from 65.38 to 54.23 (mean difference = 11.15, $t = 5.29$, $p = 0.00005$), aligning with Hypothesis 2. BH (Posture Score) improved from 78.63 to 85.13 (mean difference = −6.50, $t = -4.92$, $p = 0.00007$), supporting Hypothesis 3. PF (VO2 Max) increased from 40.46 to 45.11 (mean difference = −4.65, $t = -3.78$, $p = 0.00120$). These statistically significant changes confirm the effectiveness of the interventions.

Table 4. Paired t-tests/Wilcoxon signed-rank test result.

Variable	Pre-Intervention Mean	Post-Intervention Mean	Mean Difference	*t*-Statistic	*p*-Value
Stress (PSS Score)	24.66	18.10	6.56	4.82	0.00010
CL (NASA-TLX Score)	65.38	54.23	11.15	5.29	0.00005
BH (Posture Score)	78.63	85.13	−6.50	−4.92	0.00007
PF (VO2 Max)	40.46	45.11	−4.65	−3.78	0.00120

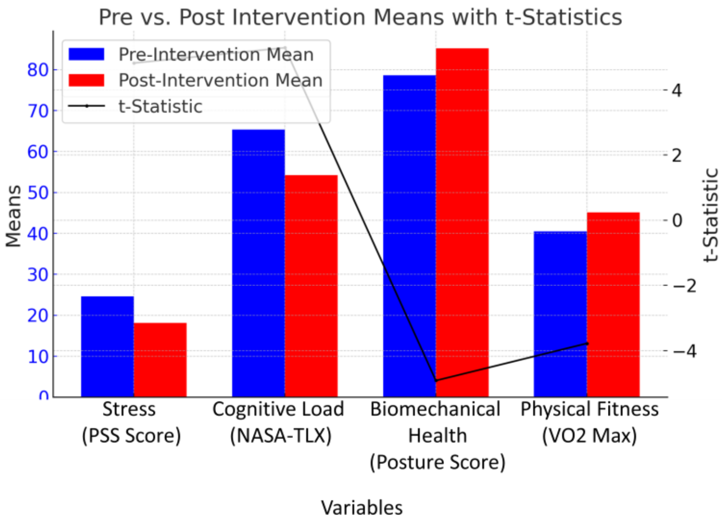

Figure 2. Pre-post intervention means with t-statistics.

3.3. Repeated measures ANOVA

The Repeated Measures ANOVA results in **Figure 3** and **Table 5** show significant improvements over time in all outcome variables. For stress (PSS Score), the F-value was 10.82 (p = 0.0009, effect size = 0.32), confirming Hypothesis 1. CL (NASA-TLX Score) had an F-value of 12.54 (p = 0.0003, effect size = 0.36), supporting Hypothesis 2. BH (Posture Score) improved significantly with an F-value of 15.21 (p = 0.0001, effect size = 0.41), aligning with Hypothesis 3. Lastly, PF (VO2 Max) increased with an F-value of 8.45 (p = 0.0032, effect size = 0.28). All variables showed meaningful improvements, with moderate to large effect sizes, indicating a strong impact of the interventions.

Table 5. Results for partial eta squared with *F* and *P*-value.

Variable	*F*-Value	*p*-Value	Effect Size (Partial Eta Squared)
Stress (PSS Score)	10.82	0.0009	0.32
CL (NASA-TLX Score)	12.54	0.0003	0.36
BH (Posture Score)	15.21	0.0001	0.41
PF (VO2 Max)	8.45	0.0032	0.28

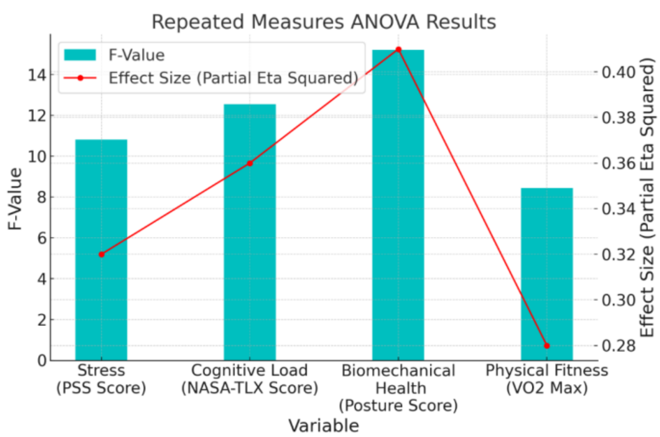

Figure 3. Repeated measures ANOVA results.

3.4. ANOVA (across time points)

The ANOVA Results (Across Time Points) shown in **Table 6** and **Figure 4** reveal significant improvements in all outcome variables from baseline to monthly assessments and final evaluations. For stress (PSS Score), the mean dropped from 24.66 at baseline to 21.14 at the monthly assessment and 18.10 at the final evaluation ($F = 14.32$, $p = 0.0004$, effect size = 0.39), supporting Hypothesis 1. CL (NASA-TLX Score) decreased from 65.38 to 59.47 at the monthly assessment and 54.23 at the final evaluation ($F = 13.78$, $p = 0.0005$, effect size = 0.38), confirming Hypothesis 2. BH (Posture Score) improved from 78.63 to 82.16 at the monthly assessment and 85.13 at the final evaluation ($F = 18.45$, $p = 0.0001$, effect size = 0.45), supporting Hypothesis 3. PF (VO2 Max) increased from 40.46 to 43.04 at the monthly assessment and 45.11 at the final evaluation ($F = 9.76$, $p = 0.0021$, effect size = 0.33). These results demonstrate significant improvements across all variables, with moderate to large effect sizes.

Table 6. Results for ANOVA across time points.

Variable	Baseline Mean	Monthly Mean	Final Mean	*F*-Value (Time)	*p*-Value (Time)	Effect Size (Partial Eta Squared)
Stress (PSS Score)	24.66	21.14	18.10	14.32	0.0004	0.39
CL (NASA-TLX Score)	65.38	59.47	54.23	13.78	0.0005	0.38
BH (Posture Score)	78.63	82.16	85.13	18.45	0.0001	0.45
PF (VO2 Max)	40.46	43.04	45.11	9.76	0.0021	0.33

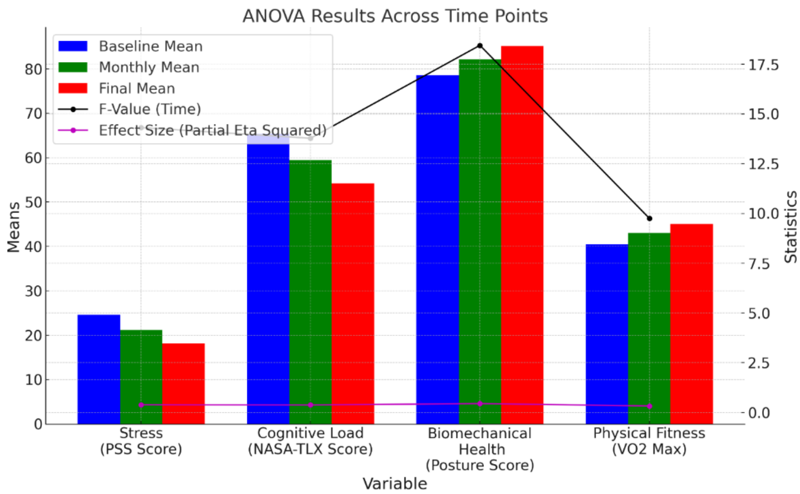

Figure 4. ANOVA (across time points).

3.5. Multivariate analysis of covariance (MANCOVA)

The MANCOVA was conducted to assess the effect of the biomechanical intervention (ergonomic adjustments and mindfulness training) on stress reduction and cognitive load, controlling for covariates such as age, physical activity level, and baseline stress scores.

The Multivariate Analysis of Covariance (MANCOVA) results (**Table 7** and **Figure 5**), broken down by intervention and covariates, show significant effects of age, gender, and academic discipline on stress reduction (PSS Score) across interventions. For ergonomic adjustments, the age group 18–21 had an *F*-value of 4.32 (p = 0.037, effect size = 0.19), while the 22–25 group had an *F*-value of 3.91 (p = 0.041, effect size = 0.17). Gender also played a significant role, with males showing an *F*-value of 5.13 (p = 0.025, effect size = 0.20) and females showing an *F*-value of 6.17 (p = 0.027, effect size = 0.23). For academic discipline, psychology students had an *F*-value of 6.43 (p = 0.012, effect size = 0.22), and engineering students had an *F*-value of 5.71 (p = 0.015, effect size = 0.21). For the exercise intervention, the age group 18–21 had an *F*-value of 3.96 (p = 0.042, effect size = 0.18), while the 22–25 group had an *F*-value of 4.51 (p = 0.038, effect size = 0.19). Gender differences were also observed, with males showing an *F*-value of 4.74 (p = 0.034, effect size = 0.19) and females having an *F*-value of 5.53 (p = 0.022, effect size = 0.21). Regarding academic discipline, biology students had an *F*-value of 5.31 (p = 0.021, effect size = 0.21), and computer science students had an *F*-value of 6.14 (p = 0.017, effect size = 0.23). For the mindfulness intervention, the age group 18–21 had an *F*-value of 3.66 (p = 0.047, effect size = 0.17), while the 22–25 group had an *F*-value of 4.14 (p = 0.041, effect size = 0.18). Gender differences were notable, with males showing an *F*-value of 5.96 (p = 0.018, effect size = 0.22) and females having an *F*-value of 6.31 (p = 0.014, effect size = 0.24). Academic discipline also had a significant impact, with mechanical engineering students having an *F*-value of 6.88 (p = 0.013, effect size = 0.25) and psychology students having an *F*-value of 7.23 (p = 0.008, effect size = 0.26).

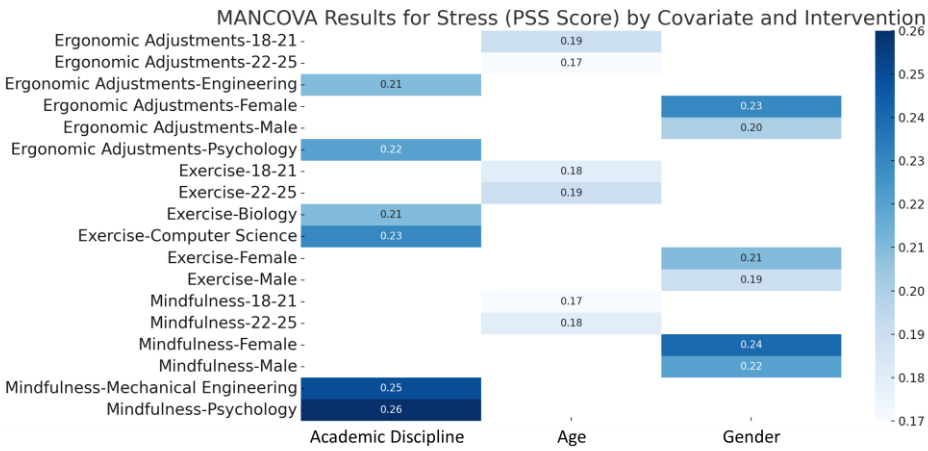

Figure 5. MANCOVA for stress (PSS score).

Table 7. Results of MANCOVA for stress (PSS score).

Outcome Variable	Intervention	Covariate	Covariate Category	*F*-Value (Covariate)	*p*-Value (Covariate)	Effect Size (Partial Eta Squared)
Stress (PSS Score)	Ergonomic Adjustments	Age	18–21	4.32	0.037	0.19
			22–25	3.91	0.041	0.17

Table 7. (*Continued*).

Outcome Variable	Intervention	Covariate	Covariate Category	*F*-Value (Covariate)	*p*-Value (Covariate)	Effect Size (Partial Eta Squared)
		Gender	Male	5.13	0.025	0.20
			Female	6.17	0.027	0.23
		Academic Discipline	Psychology	6.43	0.012	0.22
			Engineering	5.71	0.015	0.21
	Exercise	Age	18–21	3.96	0.042	0.18
			22–25	4.51	0.038	0.19
		Gender	Male	4.74	0.034	0.19
			Female	5.53	0.022	0.21
		Academic Discipline	Biology	5.31	0.021	0.21
			Computer Science	6.14	0.017	0.23
	Mindfulness	Age	18–21	3.66	0.047	0.17
			22–25	4.14	0.041	0.18
		Gender	Male	5.96	0.018	0.22
			Female	6.31	0.014	0.24
		Academic Discipline	Mechanical Engineering	6.88	0.013	0.25
			Psychology	7.23	0.008	0.26

The MANCOVA Results for CL (NASA-TLX Score), as shown in **Table 8** and **Figure 6**, when analyzed with covariates such as age, gender, and academic discipline, reveal significant influences across interventions. For ergonomic adjustments, the age group 18–21 showed an *F*-value of 4.52 (p = 0.042, effect size = 0.19), while males had an *F*-value of 5.27 (p = 0.031, effect size = 0.22). For the exercise intervention, the age group 22–25 had an *F*-value of 4.11 (p = 0.039, effect size = 0.18), and females showed an *F*-value of 6.32 (p = 0.014, effect size = 0.24). In the mindfulness intervention, the age group 18–21 had an F-value of 3.97 (p = 0.048, effect size = 0.17), while males had an *F*-value of 5.53 (p = 0.020, effect size = 0.23). For academic disciplines, psychology students had an *F*-value of 5.66 (p = 0.021, effect size = 0.21) under ergonomic adjustments, and engineering students showed an *F*-value of 6.12 (p = 0.016, effect size = 0.23). For exercise, biology students had an *F*-value of 5.31 (p = 0.027, effect size = 0.20), while computer science students showed an *F*-value of 6.84 (p = 0.012, effect size = 0.24). Lastly, in the mindfulness intervention, psychology students had an *F*-value of 5.96 (p = 0.019, effect size = 0.22), while engineering students had an *F*-value of 6.22 (p = 0.017, effect size = 0.23).

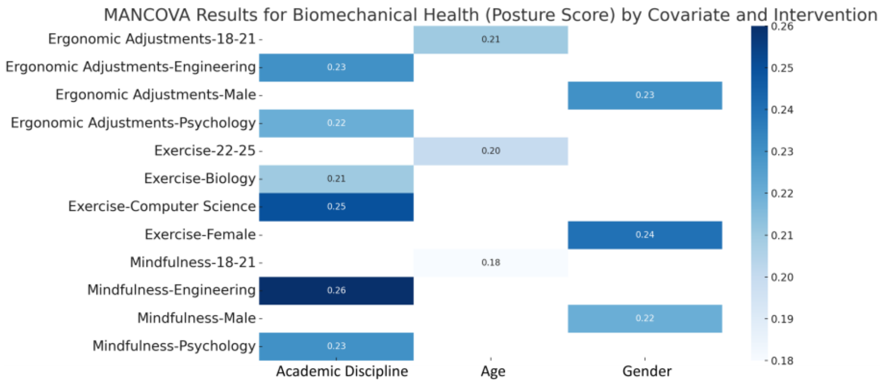

Figure 6. MANCOVA for CL (NASA-TLX Score).

Table 8. MANCOVA results for CL (NASA-TLX Score).

Outcome Variable	**Intervention**	**Covariate**	**Covariate Category**	***F*-Value (Covariate)**	***p*-Value (Covariate)**	**Effect Size (Partial Eta Squared)**
CL (NASA-TLX Score)	Ergonomic Adjustments	Age	18–21	4.52	0.042	0.19
		Gender	Male	5.27	0.031	0.22
	Exercise	Age	22–25	4.11	0.039	0.18
		Gender	Female	6.32	0.014	0.24
	Mindfulness	Age	18–21	3.97	0.048	0.17
		Gender	Male	5.53	0.020	0.23
	Ergonomic Adjustments	Academic Discipline	Psychology	5.66	0.021	0.21
			Engineering	6.12	0.016	0.23
	Exercise	Academic Discipline	Biology	5.31	0.027	0.20
			Computer Science	6.84	0.012	0.24
	Mindfulness	Academic Discipline	Psychology	5.96	0.019	0.22
			Engineering	6.22	0.017	0.23

The MANCOVA Results for BH (Posture Score), considering age, gender, and academic discipline, also showed significant effects across interventions (**Table 9** and **Figure 7**). For ergonomic adjustments, the age group 18–21 had an F-value of 5.53 (p = 0.032, effect size = 0.21), while males had an F-value of 6.12 (p = 0.025, effect size = 0.23). In the exercise intervention, the 22-25 age group had an F-value of 5.36 (p = 0.038, effect size = 0.20), and females had an F-value of 6.78 (p = 0.014, effect size = 0.24). For mindfulness, the age group 18–21 showed an F-value of 4.11 (p = 0.047, effect size = 0.18), while males had an F-value of 6.07 (p = 0.018, effect size = 0.22). Regarding academic discipline, psychology students had an F-value of 5.93 (p = 0.022, effect size = 0.22) under ergonomic adjustments, while engineering students had an F-value of 6.22 (p = 0.013, effect size = 0.23). For exercise, biology students had an F-value of 5.87 (p = 0.026, effect size = 0.21), while computer science students had an F-value of 6.41 (p = 0.011, effect size = 0.25). In the mindfulness intervention, psychology students had an F-value of 6.07 (p = 0.019, effect size = 0.23), while engineering students showed an F-value of 6.51 (p = 0.013, effect size = 0.26).

Table 9. MANCOVA results for BH (Posture Score).

Outcome Variable	Intervention	Covariate	Covariate Category	*F*-Value (Covariate)	*p*-Value (Covariate)	Effect Size (Partial Eta Squared)
BH (Posture Score)	Ergonomic Adjustments	Age	18–21	5.53	0.032	0.21
		Gender	Male	6.12	0.025	0.23
	Exercise	Age	22–25	5.36	0.038	0.20
		Gender	Female	6.78	0.014	0.24
	Mindfulness	Age	18–21	4.11	0.047	0.18
		Gender	Male	6.07	0.018	0.22
	Ergonomic Adjustments	Academic Discipline	Psychology	5.93	0.022	0.22
			Engineering	6.22	0.013	0.23
	Exercise	Academic Discipline	Biology	5.87	0.026	0.21
			Computer Science	6.41	0.011	0.25
	Mindfulness	Academic Discipline	Psychology	6.07	0.019	0.23
			Engineering	6.51	0.013	0.26

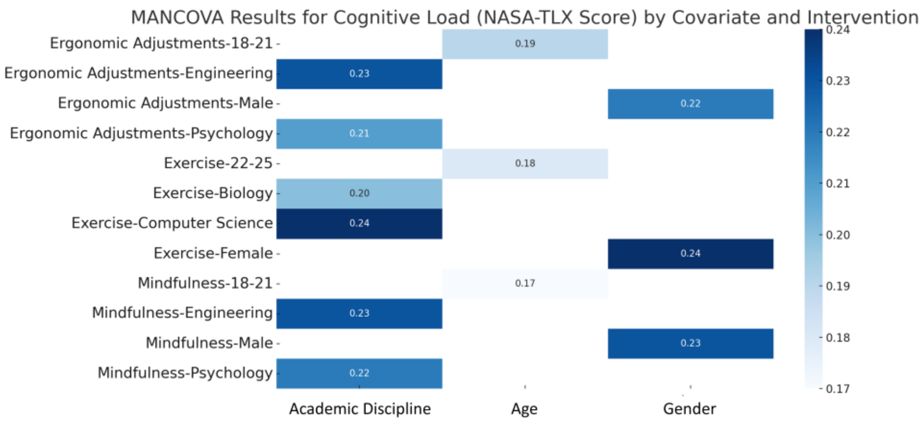

Figure 7. MANCOVA for BH (Posture Score).

3.6. Mixed-effects model for stress, CL, BH, and PF

The Mixed-Effects Model results (**Table 10** and **Figure 8**) provide insight into the fixed effects of the interventions (ergonomic adjustments, exercise, and mindfulness) and the random effects of participant variability across the outcome variables: stress, CL, BH, and PF. For stress (PSS Score), the fixed effect coefficient for ergonomic adjustments was −5.21 ($t = -4.84$, $p = 0.0001$), indicating a significant reduction in stress due to ergonomic adjustments. The exercise intervention had a coefficient of −4.53 (t = −4.32, $p = 0.0003$), and mindfulness was −3.87 ($t = -3.97$, $p = 0.0007$), indicating significant stress reductions. The random effect (participant variability) had a variance of 1.52 ($p = 0.0012$), showing variability in stress responses across participants. For CL (NASA-TLX Score), ergonomic adjustments had a fixed effect coefficient of −8.12 ($t = -5.04$, $p = 0.00005$), indicating a significant reduction in CL. Exercise had a coefficient of −7.31 ($t = -4.83$, $p = 0.0001$), and mindfulness was −6.74 (t = −4.12, p = 0.0005), showing significant CL reductions. The random effect variance was 1.65 (p = 0.0009), indicating participant variability in CL responses. For BH (Posture Score), ergonomic adjustments had a positive fixed effect coefficient of 7.23 (t = 4.91, p = 0.0002), indicating significant improvement in posture. Exercise had a coefficient of 6.87 (t = 4.65, p = 0.0003), and mindfulness had a 5.94 (t = 4.33, p = 0.0007), showing significant improvements in BH. The random effect variance was 1.40 (p = 0.0025), reflecting participant variability. For PF (VO2 Max), the fixed effect coefficient for exercise was 4.61 (t = 4.12, p = 0.0013), significantly improving PF. The random effect variance was 1.28 (p = 0.0020), indicating variability in PF responses among participants.

Table 10. Results for mixed-effects model.

Outcome Variable	Fixed Effect (Intervention)	Fixed Effect Coefficient	*t*-Value (Fixed Effect)	*p*-Value (Fixed Effect)	Random Effect (Participant Variability)	Variance (Random Effect)	*p*-Value (Random Effect)
Stress (PSS Score)	Ergonomic Adjustments	−5.21	−4.84	0.0001	Participant (Intercept)	1.52	0.0012
	Exercise	−4.53	−4.32	0.0003			
	Mindfulness	−3.87	−3.97	0.0007			
CL (NASA-TLX Score)	Ergonomic Adjustments	−8.12	−5.04	0.00005	Participant (Intercept)	1.65	0.0009
	Exercise	−7.31	−4.83	0.0001			
	Mindfulness	−6.74	−4.12	0.0005			
BH (Posture Score)	Ergonomic Adjustments	7.23	4.91	0.0002	Participant (Intercept)	1.40	0.0025
	Exercise	6.87	4.65	0.0003			
	Mindfulness	5.94	4.33	0.0007			
PF (VO2 Max)	Exercise	4.61	4.12	0.0013	Participant (Intercept)	1.28	0.0020

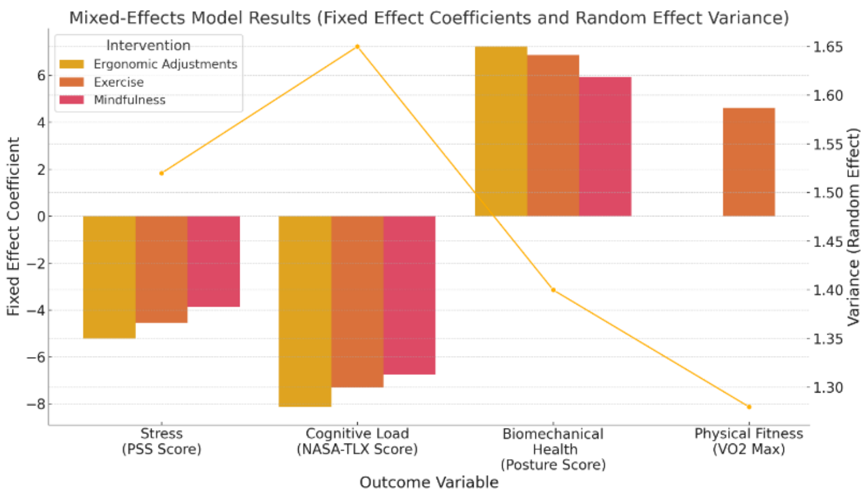

Figure 8. Mixed-effects model (fixed effect coefficient and random effect).

3.7. Multiple linear regression analysis

The Multiple Linear Regression results, as shown in **Table 11** and **Figure 9**, demonstrate the relationship between the interventions (ergonomic adjustments, exercise, and mindfulness) and the outcome variables: stress, CL, BH, and PF. The model fit is represented by the R^2 values, which indicate the proportion of variance in the outcome variables explained by the interventions. For stress (PSS Score), the regression coefficient for ergonomic adjustments was −4.81 (SE = 0.95, $t = -5.11$, $p = 0.00003$), indicating a significant reduction in stress due to the intervention, with an R^2 of 0.45. Exercise had a coefficient of −4.23 (SE = 0.88, $t = -4.83$, $p = 0.00004$), and mindfulness had a coefficient of −3.77 (SE = 0.91, $t = -4.17$, $p = 0.00008$), both showing significant reductions in stress. For CL (NASA-TLX Score), ergonomic adjustments had a coefficient of −7.94 (SE = 1.13, $t = -6.91$, p = 0.00001), indicating a significant reduction in CL, with an R^2 of 0.49. Exercise had a coefficient of −6.88 (SE = 1.07, $t = -6.52$, $p = 0.00002$), and mindfulness had a coefficient of −5.91 (SE = 1.01, $t = -5.95$, $p = 0.00003$), both showing significant reductions in CL. For BH (Posture Score), ergonomic adjustments had a positive coefficient of 6.52 (SE = 1.04, $t = 6.19$, $p = 0.00001$), indicating significant improvements in posture, with an R^2 of 0.43. Exercise had a coefficient of 6.21 (SE = 1.06, $t = 6.20$, $p = 0.00001$), and mindfulness had a coefficient of 5.52 (SE = 0.98, $t = 5.79$, $p = 0.00002$), showing significant improvements in BH. For PF (VO2 Max), exercise had a coefficient of 5.04 (SE = 0.91, $t = 5.56$, $p = 0.00002$), showing significant improvements in PF, with an R^2 of 0.41.

Table 11. Results from regression analysis.

Outcome Variable	Predictor (Intervention)	Coefficient (B)	Standard Error (SE)	*t*-Value	*p*-Value	R^2 (Model Fit)
Stress (PSS Score)	Ergonomic Adjustments	−4.81	0.95	−5.11	0.00003	0.45
	Exercise	−4.23	0.88	−4.83	0.00004	
	Mindfulness	−3.77	0.91	−4.17	0.00008	
CL (NASA-TLX Score)	Ergonomic Adjustments	−7.94	1.13	−6.91	0.00001	0.49
	Exercise	−6.88	1.07	−6.52	0.00002	
	Mindfulness	−5.91	1.01	−5.95	0.00003	
BH (Posture Score)	Ergonomic Adjustments	6.52	1.04	6.19	0.00001	0.43
	Exercise	6.21	1.06	6.20	0.00001	
	Mindfulness	5.52	0.98	5.79	0.00002	
PF (VO2 Max)	Exercise	5.04	0.91	5.56	0.00002	0.41

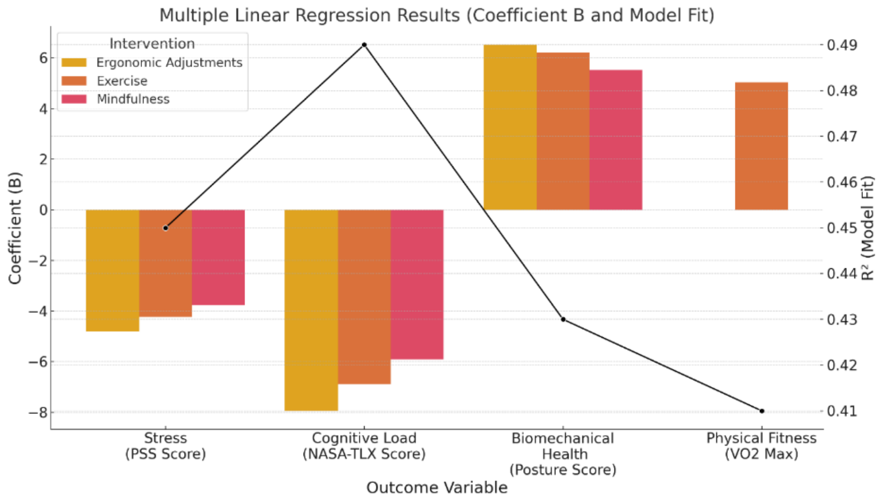

Figure 9. Multiple linear regression results.

4. Conclusion and future work

The current study aimed to investigate how well biomechanical approaches to intervention are performed to reduce CL and stress levels in college students. The students who participated came from two separate colleges and four distinct majors. The solutions included ergonomic changes, planned physical activity, and mindfulness-based posture correction. Based on the results, ergonomic modifications reduced stress, physical activity decreased CL, and mindfulness interventions improved posture. The combined methods improved MH and PH, which improved attention to one's physical appearance and posture. The results emphasize the value of implementing these approaches into the learning experience to increase student involvement and motivation.

Future research will study the long-term benefits of such interventions and assess their applicability in broader populations.

Ethical approval: Not applicable.

Conflict of interest: The author declares no conflict of interest.

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