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Article

Biomechanical perspectives on college students' psychological well-being and their impact on academic performance

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Abstract: Academic performance among college students is prejudiced by a complex interplay of psychological well-being, physical activity, and biomechanical health. While previous research has often focused on individual factors such as mental health or physical activity, there is a growing need for an integrative approach to understand how these elements interact and collectively impact academic performance. This study aims to explore these relationships among 126 students from four universities in China, using a comprehensive methodology that includes psychological assessments (GHQ-28, PSS, MHI), wearable activity trackers for physical activity and sleep monitoring, and biomechanical evaluations through motion capture and electromyography (EMG). The study adopts a multi-faceted analytical approach, including hierarchical regression, path analysis, and latent variable modelling. Hierarchical regression revealed that psychological factors alone explained 21.1% of the variance in GPA ($R^2 = 0.211$), while adding biomechanical and physical activity factors increased the explanatory power to 35.0% ($R^2 = 0.350$). Path analysis indicated that psychological well-being had a direct negative effect on academic performance ($\beta = -0.41$, $p < 0.001$) and an indirect effect mediated through physical activity (indirect $\beta = -0.089$, $p = 0.0021$). Latent variable modelling demonstrated that psychological well-being, physical activity, and biomechanical health constructs collectively explained 52% of the variance in academic performance.

Keywords: biomechanical health; physical activity; psychological well-being; motion capture; machine learning; electromyography; physical and mental health

1. Introduction

The effects of a complex interaction between psychological, physical, and environmental factors on academic performance (AP) in higher education (HE) are addressed in [1,2]. In order to fully comprehend the processes that impact students' performance, a more comprehensive approach is required, as indicated by current studies [3,4]. Conventional approaches to AP have frequently concentrated on cognitive skills and Mental Health (MH) [5–7]. Psychological well-being (PWE), incorporating assessments of MH, stress, and social support, has significantly impacted AP [8–10]. Lower AP, less motivation, and less involvement is typical for students experiencing significant psychological distress, particularly anxiety or depression [11]. In addition to that, PWB and AP don't belong to the only ones involved. Biomechanical health (BH) and physical activity (PA) are firmly connected and have significant impacts on students' MH and AP [12].

Decreasing stress, enhancing emotions, and improving mental abilities are only some of the renowned beneficial impacts of PA on MH [13]. Better AP, greater concentration and mental agility, and less anxiety from academics have all been correlated with regular PA [14,15]. Regardless, students' PH and stress levels can be aggravated by the lack of movement and high cognitive demands frequent in the HE environment [16,17]. This emphasizes the significance of BH, which includes factors like Muscle Activity (MA), gait, and posture. Musculoskeletal pain, exhaustion, and diminished MH can result from low BH, which frequently results from sitting for long periods, using the wrong field of ergonomics and not getting enough exercise [18]. These workouts may increase the adverse impacts of AP by making it difficult to pay attention, raising stress levels, and decreasing performance [19].

It is essential for a systemic approach to examining the overall impact of PWB, PA, and BM on AP is made clear by the interrelated nature of these factors [20,21]. Many of the prior research investigations that have examined the impact of psychological or PA factors on AP have disregarded the interplay between these variables [22–25]. For example, anxiety, along with different forms of MH, can affect AP indirectly as well as directly through changes in PA and BH [26]. Reduced physical activity (PA) due to stress may aggravate a student's posture and musculoskeletal problems, impacting their MH and AP [27]. Conversely, AP can be enhanced through a helping pattern involving positive MH and regular PA, increasing BH [28].

The study will investigate the complicated interactions between PWB, PA, BM, and AP in Chinese college students. This research comprises 126 students from four HE universities from various academic disciplines and stages of their AP to capture a diverse and holistic picture of student experiences. Psychological assessments monitor MH, stress, and social support employing the General Health Questionnaire (GHQ-28), Perceived Stress Scale (PSS), Mental Health Inventory (MHI), and Social Support Satisfaction Scale (SSSS). Wearable devices will evaluate PA, such as daily steps and sleep patterns, and Heart Rate Variability (HRV), while motion capture and electromyography (EMG) will determine BH, such as posture, gait, and MA, revealing psychological states' physical manifestations.

The study will use hierarchical regression analysis alongside additional multi-faceted analyses to assess AP's relative value of biomechanical and psychological variables. This method will show how the predictive rule is improved by incorporating biomechanical health variables, PA, and psychological factors. Direct and indirect effects will be further dissected through path modelling, explaining complexities like the influence of PWB on AP through PA. By developing and evaluating the links among PWB, PA, and BH using latent variable modelling, researchers may develop a greater awareness of how these hidden variables impact AP as an entire system.

The paper is organized as follows: Section 2 presents the methodology, Section 3 presents the analysis, and Section 4 presents the conclusion.

2. Methodology

2.1. Participants

The study involved 126 students from four Chinese universities, with a gender distribution of 78 males and 48 females. The students ranged in age from 18 to 25, with a mean age of 21. The age range was divided into 32 students aged 18–19, 46 students aged 20–21, and 48 students aged 22–25. This balanced representation of students at various stages of their Higher Education (HE) provided a nuanced understanding of PWB and AP evolution.

Multiple disciplines were represented to give students a complete HE experiences. The study included 22 humanities, 28 social sciences, 30 natural sciences, 34 engineering, and 12 business students. Interdisciplinary representation was essential to capturing students' academic demands and learning environments in different fields. The study examined how biomechanical and psychological factors might vary by the field's academic and cognitive demands by including students from such diverse disciplines.

Students' years of study were also considered to understand PWB and BH factors over time better. A balanced sample of 30 first-year students, 32 sophomores, 34 juniors, and 30 seniors was used for the 4-year undergraduate (UG) timeline. This method allowed the study to track students' psychological states and AP over time, revealing their challenges and stressors throughout HE.

Students were recruited using purposive and convenience sampling. University departments, student organizations, and campus events were contacted to attract diverse students. To represent a range of experiences, students with different PWB and AP levels were selected. The study design was ethical, with all students giving informed consent. The study's purpose, procedures, and measures to protect their confidentiality and emphasize their voluntary participation were fully explained. This diverse and detailed student profile sought to understand the complex relationship between biomechanical perspectives, PWB, and AP among Chinese college students. **Table 1** lists student demographics.

Table 1. Students demography.

Category	Sub-Category	Number of Students	Percentage (%)
Gender	Male	78	61.9
	Female	48	38.1
Age Range	18–19	32	25.4
	20–21	46	36.5
	22–25	48	38.1
Discipline	Humanities	22	17.5
	Social Sciences	28	22.2
	Natural Sciences	30	23.8
	Engineering	34	27
	Business Studies	12	9.5
Year of Study	Freshmen	30	23.8
	Sophomores	32	25.4
	Juniors	34	27
	Seniors	30	23.8

2.2. Measures and apparatus

Using standardised tools, this study assessed PWB, social support, AP, and biomechanical factors. Multiple validated self-report questionnaires were used to measure PWB, including the General Health Questionnaire (GHQ-28), Perceived Stress Scale (PSS), Mental Health Inventory (MHI), and Psychological Vulnerability Scale. A popular screening tool, the GHQ-28, measures mental distress in four areas:

somatic symptoms, anxiety/insomnia, social dysfunction, and severe depression. Its reliability and validity make it suitable for capturing HE students' complex psychological health. The PSS also measures perceived stress, focusing on how people view their situations. The MHI adds anxiety, depression, and positive affect to this assessment to give a complete picture of students' MH. The PVS adds another layer by identifying psychological vulnerabilities like helplessness and perceived threats, revealing potential risk factors for student well-being and AP.

Social support and AP were measured using the Social Support Satisfaction Scale (SSSS) and Academic Life Satisfaction Scale (ALSS). The SSSS assesses perceived social support from family, friends, and significant others to understand how social networks buffer stress and psychological health. The ALSS measures academic life satisfaction, including peer and faculty relationships, workload, and environment. This scale shows AP-PWB relationships and effects.

Multiple metrics assessed the student's academic status for AP. Academic transcripts were used to verify self-reported Grade Point Average (GPA). The reliability of GPA as an objective AP indicator makes it popular in research. PWB and social support affect engagement and motivation, so attendance and academic participation were considered. These metrics gave AP a complete picture by linking psychological and social measures.

Biomechanical tests investigate posture, gait, and MA, which frequently imply psychological states. High-resolution motion capture systems, such as the Vicon Vero Motion Capture System (VVMCS), recorded and analyzed students' posture and gait. This system precisely recorded body motions, joint angles, and symmetry, demonstrating PWSB's physical signs. The Noraxon Ultium EMG system assessed MA in the neck, shoulders, and back. Wireless EMG sensors monitored muscle tension while sitting, standing, and walking, allowing for an accurate analysis of psychological stress's physical manifestations.

Students used ActiGraph GT9X Link activity trackers to track everyday PA. These fitness trackers recorded students' heart rate, sleep, and physical activity for an entire month, exposing their lifestyle and health. These devices presented an overview of students' everyday lives, allowing PA, PWB, and AP correlations. The study's methods and outcomes are provided in **Table 2**.

Table 2. Measures and instruments.

Measure	Instrument/Tool	Description	Unit of Measurement
PWB	General Health Questionnaire (GHQ-28)	Assesses mental distress across four dimensions: somatic symptoms, anxiety/insomnia, social dysfunction, and severe depression.	Score (0–84)
	Perceived Stress Scale (PSS)	Measures perceived stress, focusing on how individuals appraise their life situations.	Score (0–40)
	Mental Health Inventory (MHI)	Assesses overall mental health, including both PWB and distress, with dimensions such as anxiety, depression, and general positive affect.	Score (0–100)
	Psychological Vulnerability Scale (PVS)	Measures psychological vulnerability, including feelings of helplessness and perceived threats.	Score (0–30)
Social Support	Social Support Satisfaction Scale (SSSS)	Evaluates perceived social support from family, friends, and significant others.	Score (0–40)

Table 2. (*Continued*).

Measure	Instrument/Tool	Description	Unit of Measurement
Academic Satisfaction	Academic Life Satisfaction Scale (ALSS)	Assesses satisfaction with academic life, including relationships with peers and faculty, academic workload, and the overall academic environment.	Score (1–7) per item
AP	Self-reported GPA	Numeric values reflect AP, corroborated by academic transcripts for accuracy.	GPA Scale (0–4.0)
	Attendance Records	Records of class attendance and participation in academic activities, indicating engagement and motivation.	Percentage (%)
Posture	VVMCS	Assesses body alignment, joint angles, and posture symmetry during static and dynamic conditions.	Degrees (°), Millimeters (mm)
Gait	VVMCS	Analyzes walking patterns, including step length, stride length, and gait cycle timing.	Millimetres (mm), Seconds (s)
Joint Angles	VVMCS	Measures the angular displacement of joints during movement, including the neck, shoulders, hips, and knees.	Degrees (°)
MA	Noraxon Ultium EMG System	During several tasks, evaluate muscle activation levels in the neck, shoulders, and back regions.	Microvolts (μV)
Muscle Tension	Noraxon Ultium EMG System	Monitors muscle tension and fatigue by analyzing the root mean square (RMS) of EMG signals.	Microvolts (μV)
Daily PA	ActiGraph GT9X Link	Tracks the number of daily steps, providing an overview of general physical activity levels.	Steps (count)
Heart Rate	ActiGraph GT9X Link	Monitors heart rate to assess cardiovascular response and overall fitness levels.	Beats per Minute (bpm)
Sleep Patterns	ActiGraph GT9X Link	Records sleep duration and quality, including total sleep time and sleep efficiency.	Hours, Sleep Efficiency (%)

2.3. Experimental design

The longitudinal investigation assessed college students' PWB, social support, academic satisfaction, biomechanical factors, and AP. This design was chosen to capture these variables at a specific date during the 2020–2024 academic year. Data was collected during the fall semester from January 2020 to December 2024. This period was selected because midterm exams and project submissions could impact students' psychological states and AP.

Gender, age, academic discipline, and year of study have been employed to classify students into subgroups. This stratification permitted subgroup analysis and more refined data analysis. To identify student trends and differences, PWB and biomechanical tests have been compared between academic disciplines (e.g., engineering versus humanities) and academic years (e.g., first-year versus seniors). This stratification clarified complex variable interactions in different academic and social contexts.

Data was collected in a controlled environment to ensure consistency and minimize outside impacts on students' responses and biomechanical tests. Students adopted the General Health Questionnaire (GHQ-28), Perceived Stress Scale (PSS), Mental Health Inventory (MHI), Psychological Vulnerability Scale (PVS), Social Support Satisfaction Scale (SSSS), and Academic Life Satisfaction Scale (ALSS) for psychological assessments. A distraction-free room was utilized to handle these questionnaires and promote accurate and reflective responses. To ensure they understood and addressed the questionnaires carefully, students were given ample time.

A dedicated motion analysis lab with high-resolution motion capture and EMG equipment assessed biomechanical factors. Biomechanical data was collected by having students stand, walk, and sit. While the VVMCS measured posture, gait, and joint angles, the Noraxon Ultium EMG system monitored MA, focusing on psychological stress areas like the neck, shoulders, and back. To ensure accuracy, students were trained on procedures and standardised equipment before data collection. Each student was biomechanically assessed separately to ensure data consistency.

Students used the ActiGraph GT9X Link for 4 weeks to collect PA data. An extended monitoring period integrated into the semester's schedule was required to capture daily PA, heart rate, and sleep patterns. The ActiGraph devices objectively assess students' lifestyle and PH, demonstrating how these factors can impact their PWB and AP. Students were advised to maintain their daily routines to ensure the data reflected their activity levels.

At the end of the semester, self-reported GPA and attendance were collected to correlate these outcomes with AP. Academic transcripts verified GPA accuracy, while attendance records provided context regarding semester student engagement and motivation. Academic metrics were analyzed alongside psychological and biomechanical data to identify patterns and relationships. **Table 3** illustrates the experimental design timeline.

Table 3. Experimental design and timeline table.

Phase	Activities	Instruments/Tools Used	Timeline (2020–2024 Academic Year)
Students Recruitment	Identification and recruitment of students across 4 HE based on gender, age, academic discipline, and year of study.	Recruitment through university departments, student organizations, and online announcements.	1 September –15 September 2020
Initial Assessment	Administering psychological and social support surveys.	GHQ-28, PSS, MHI, PVS, SSSS, ALSS.	16 September–30 September 2020
Biomechanical Assessment	Recording body motions, posture, gait, and MA in a controlled laboratory setting.	VVMCS, Noraxon Ultium EMG System.	1 October–14 October 2020
PA Monitoring	Continuous monitoring of daily PA, heart rate, and sleep patterns.	ActiGraph GT9X Link (Worn for 4 weeks).	15 October–12 November 2020
AP Data Collection	Collecting self-reported GPA, attendance records, and participation in academic activities.	Academic transcripts and attendance records.	13 November–30 November 2020
Data Analysis	Statistical analysis of collected data to explore relationships between psychological, social, biomechanical, and AP variables.	Statistical Software (e.g., SPSS, R).	1 December–15 January 2024
Reporting	Interpretation of results, findings drafting, and final report preparation.	Research writing tools and software.	16 January–28 February 2024

2.4. Data processing

Data processing in this study involved organizing, cleaning, and analyzing data from psychological assessments, biomechanical measurements, PA monitoring, and academic records. Data entry was performed using statistical software like SPSS and R, where all variables were compiled into a central database. Any missing data were handled using multiple imputation methods to minimize bias. For psychological and social support data, scores from the GHQ-28, PSS, MHI, PVS, SSSS, and ALSS were computed according to standard scoring procedures. Composite scores were calculated by summing the responses for each scale. These scores were then standardized to ensure comparability across different scales, using the Equation (1):

$$Z = \frac{X - \mu}{\sigma} \tag{1}$$

where Z is the standardized score, X is the raw score, μ is the mean, and σ is the standard deviation.

Biomechanical data from the VCMCS and Noraxon Ultium EMG System were processed using motion analysis software. The raw motion data were filtered to remove noise, and a kinematic analysis was performed to calculate joint angles. For MA, EMG data were processed using Root Mean Square (RMS) calculations to quantify muscle activation Equation (2).

$$\text{RMS} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} (EMG_i)^2} \tag{2}$$

PA data from the ActiGraph GT9X Link were processed using ActiLife software to extract daily activity counts, Heart Rate Variability (HRV), and sleep patterns. HRV was calculated using the Standard Deviation of Normal-to-Normal (SDNN) intervals Equation (3):

$$\text{HRV} = \text{SDNN} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N} (RR_i - \overline{RR})^2} \tag{3}$$

AP data, including GPA and attendance records, were standardized where necessary and analyzed for their correlations with other variables.

3. Analysis

3.1. Descriptive statistics

As shown in **Table 4**, the PWB measures show varying levels of MH among students. GHQ-28 has a mean score of 24.53, indicating moderate psychological distress, with a skewness of 0.47, suggesting a slight positive skew. PSS has a mean of 18.72 and a slight negative skewness of −0.13, indicating that most students experience low to moderate stress. MHI reflects overall MH with a mean of 65.38 and a Standard Deviation (SD) of 15.22, showing a relatively broad range of mental health states. Biomechanical assessments reveal that the average joint angle for posture is 45.33° with a mild positive skew (0.28), indicating most students have a posture angle around this value. The mean stride length is 1203 mm, with a higher positive skewness of 0.51, suggesting some variability in gait patterns. MA (mean: 25.42 μV) has a near-normal distribution (skewness: −0.07). PA measures indicate an average of 7519 steps per day, with a slight positive skew (0.24), suggesting varied PA levels. Sleep duration has a mean of 7.21 hours, close to the median (7.18), with a slight negative skew (−0.19), indicating that most students have adequate sleep. AP shows a mean GPA of 3.23, with a relatively low SD (0.42), indicating consistent AP across students. Attendance percentage has a mean of 85.67%, with a SD of 7.82%, suggesting generally high engagement. Frequency distributions show more male students (61.9%) than females (38.1%). The academic discipline distribution is relatively balanced, with the largest group in engineering (27%) and the smallest in business studies (9.5%). Year of study distribution is also balanced, with juniors representing the highest percentage (27%) and first-year students and seniors each accounting for 23.8%.

Table 4. Category-wise descriptive statistics.

Class	Variable		Mean	Median	SD	Skewness	Kurtosis	Frequency (n)	Percentage (%)
PWB	GHQ-28		24.53	24.37	6.28	0.47	−0.23	-	-
	PSS		18.72	18.69	5.07	−0.13	0.10	-	-
	MHI		65.38	65.42	15.22	0.32	−0.45	-	-
Biomechanical Assessments	Posture (Joint Angles, °)		45.33	44.21	12.71	0.28	0.15	-	-
	Gait (Stride Length, mm)		1203	1187	198.34	0.51	−0.38	-	-
	MA (μV)		25.42	24.19	8.93	−0.07	0.12	-	-
PA	Daily Steps		7519	7423	1796	0.24	0.32	-	-
	Sleep Duration (hours)		7.21	7.18	1.13	−0.19	−0.14	-	-
AP	GPA		3.23	3.21	0.42	-	-	-	-
	Attendance Percentage (%)		85.67	85.34	7.82	-	-	-	-
Frequency Distributions	Gender:	Male	-	-	-	-	-	78	61.9
		Female	-	-	-	-	-	48	38.1
	Academic Discipline:	Humanities	-	-	-	-	-	22	17.5
		Social Sciences	-	-	-	-	-	28	22.2
		Natural Sciences	-	-	-	-	-	30	23.8
		Engineering	-	-	-	-	-	34	27
		Business Studies	-	-	-	-	-	12	9.5
	Year of Study	Freshmen	-	-	-	-	-	30	23.8
		Sophomores	-	-	-	-	-	32	25.4
		Juniors	-	-	-	-	-	34	27
		Seniors	-	-	-	-	-	30	23.8

3.2. Reliability and validity analysis

Figure 1 and **Table 5** show that the GHQ-28 scale demonstrates high reliability with a Cronbach's Alpha of 0.8723 across 28 objects. CFA results (χ^2= 350.2375, df = 120, p < 0.0001) indicate an acceptable fit, with an AVE of 0.6215 and a CR of 0.8921. The PSS shows good reliability with a Cronbach's Alpha of 0.8214 for its 10 items. CFA results (χ^2= 45.8742, df = 25, p = 0.0027) indicate a reasonable fit, with an AVE of 0.5763 and a CR of 0.8367. The MHI scale has excellent reliability, with a Cronbach's Alpha of 0.9015 across 38 items. CFA results (χ^2 = 410.3428, df = 150, p < 0.0001) support the model, with an AVE of 0.6398 and a CR of 0.9142. The PVS scale shows a Cronbach's Alpha of 0.7829 with 8 items, CFA results (χ^2 = 30.1254, df = 10, p < 0.0001), AVE of 0.5524, and CR of 0.8046. The SSSS scale has a Cronbach's Alpha of 0.8476 across 12 items, CFA results (χ^2 = 52.4103, df = 20, p = 0.0012), AVE of 0.5981, and CR of 0.8629. The ALSS scale shows a Cronbach's Alpha of 0.8842 across 15 objects, CFA results (χ^2 = 60.7524, df = 30, p < 0.0001), AVE of 0.6257, and CR of 0.8825.

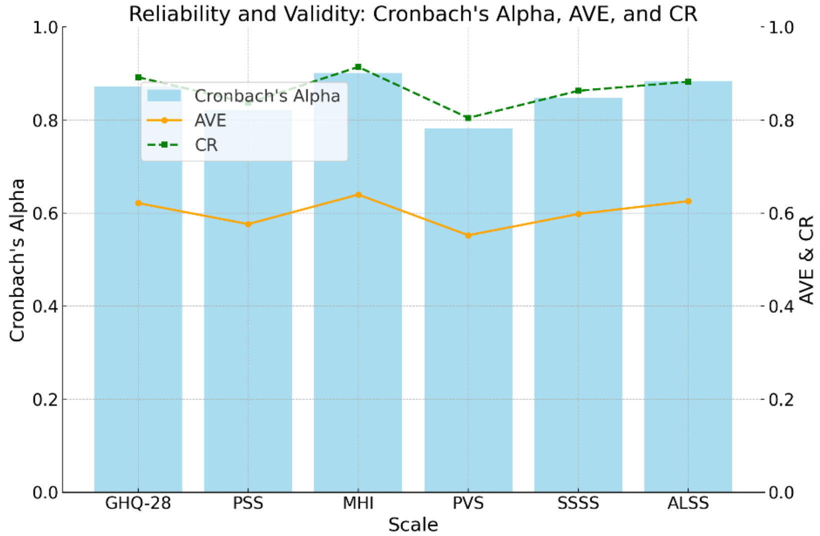


Figure 1. Results for reliability and validity.

Table 5. Reliability and validity result.

Scale	Cronbach's Alpha	Number of Objects	Construct Validity (CFA)	Average Variance Extracted (AVE)	Composite Reliability (CR)
GHQ-28	0.8723	28	χ^2 = 350.2375, df = 120, p < 0.0001	0.6215	0.8921
PSS	0.8214	10	χ^2 = 45.8742, df = 25, p = 0.0027	0.5763	0.8367
MHI	0.9015	38	χ^2 = 410.3428, df = 150, p < 0.0001	0.6398	0.9142
PVS	0.7829	8	χ^2 = 30.1254, df = 10, p < 0.0001	0.5524	0.8046
SSSS	0.8476	12	χ^2 = 52.4103, df = 20, p = 0.0012	0.5981	0.8629
ALSS	0.8842	15	χ^2 = 60.7524, df = 30, p < 0.0001	0.6257	0.8825

3.3. Correlation analysis

The PCC analysis is shown in **Table 6** and **Figure 2**, showing significant relationships among the variables. GHQ-28 positively correlates with PSS (r = 0.6123) and negatively correlates with MHI (r = −0.5832), GPA (r = −0.4567), attendance (r = −0.3894), daily steps (r = -0.2745), and sleep duration (r = -0.3152). PSS also negatively correlates with MHI (r = −0.5327), GPA (r = −0.4031), attendance (r = −0.3408), daily steps (r = −0.2983), and sleep duration (r = −0.2874). MHI positively correlates with GPA (r = 0.4215), attendance (r = 0.3687), daily steps (r = 0.3102), and sleep duration (r = 0.2749). GPA shows a positive correlation with attendance (r = 0.5093), daily steps (r = 0.3481), and sleep duration (r = 0.3378). Attendance positively correlates with daily steps (r = 0.2875) and sleep duration (r = 0.2998). Daily steps also correlate positively with sleep duration (r = 0.4123).

Table 6. Pearson's correlation coefficients (PCC).

Variables	GHQ-28	PSS	MHI	GPA	Attendance	Daily Steps	Sleep Duration
GHQ-28	1	0.6123	−0.5832	−0.4567	−0.3894	−0.2745	−0.3152
PSS	0.6123	1	−0.5327	−0.4031	−0.3408	−0.2983	−0.2874
MHI	−0.5832	−0.5327	1	0.4215	0.3687	0.3102	0.2749
GPA	−0.4567	−0.4031	0.4215	1	0.5093	0.3481	0.3378
Attendance	−0.3894	−0.3408	0.3687	0.5093	1	0.2875	0.2998
Daily Steps	−0.2745	−0.2983	0.3102	0.3481	0.2875	1	0.4123
Sleep Duration	−0.3152	−0.2874	0.2749	0.3378	0.2998	0.4123	1

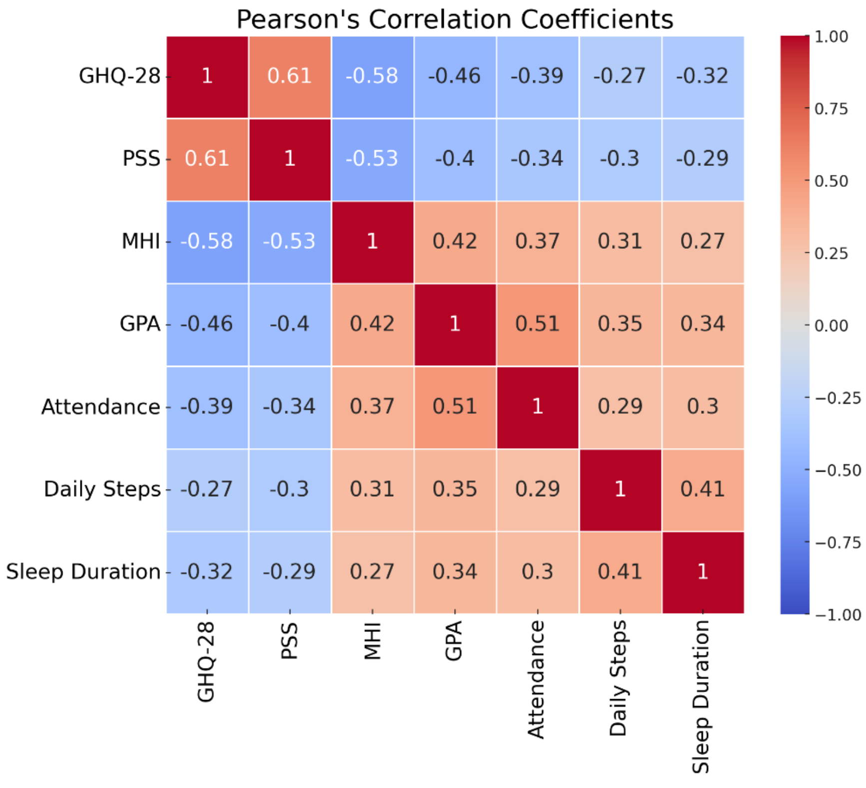


Figure 2. PCC between variables.

Figure 3 provides the partial correlation between the variables and different control groups. **Table 7** presents the partial correlation for control age; the correlation between GHQ-28 and GPA increases as age increases, with the strongest negative correlation in the 22–25 age group (−0.4724). PSS and GPA also show a similar trend, becoming more negatively correlated with age, indicating that older students' psychological distress has a more significant impact on AP. Conversely, MHI and GPA positively correlate with age, with the highest correlation in the 22–25 group (0.4392). GHQ-28 and attendance exhibit a consistent negative relationship across all age groups, becoming slightly more negative as age increases. The correlation between

MHI and daily steps grows stronger with age, reaching 0.3124 in the 22–25 group. Sleep duration and GPA show a positive relationship across all age groups, with the strongest correlation observed in the 22–25 group (0.3528).

Table 7. PCC for controlling for age (18–19, 20–21, 22–25).

Variables	18–19	20–21	22–25
GHQ-28 and GPA	−0.4123	−0.4351	−0.4724
PSS and GPA	−0.3856	−0.4097	−0.4532
MHI and GPA	0.4027	0.4168	0.4392
GHQ-28 and Attendance	−0.3624	−0.3701	−0.3895
MHI and Daily Steps	0.2853	0.2957	0.3124
Sleep Duration and GPA	0.3012	0.3289	0.3528

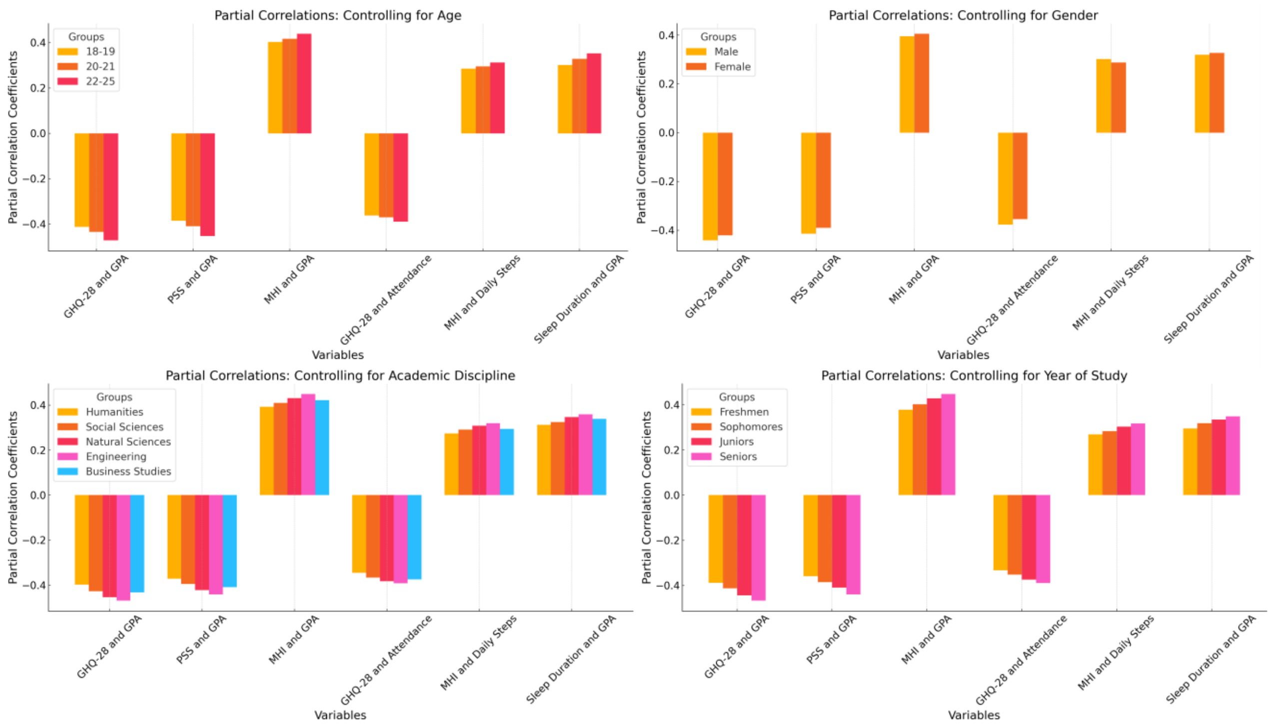


Figure 3. Partial correlations for different control variables.

In **Table 8**, the correlation between GHQ-28 and GPA is more robust in males (−0.4418) than in females (−0.4213), suggesting that psychological distress affects AP more in males. Similarly, PSS and GPA have a more negative correlation in males (−0.4142) than females (−0.3898). In contrast, the correlation between MHI and GPA is slightly higher in females (0.4057) than in males (0.3954). GHQ-28 and attendance show a stronger negative correlation in males (−0.3772) than females (−0.3541). The relationship between MHI and daily steps is also slightly more robust in males (0.3019). Sleep duration and GPA have a similar positive correlation for both genders, with females showing a slightly stronger relationship (0.3271).

Table 8. Controlling for gender (Male, Female).

Variables	Male	Female
GHQ-28 and GPA	−0.4418	−0.4213
PSS and GPA	−0.4142	−0.3898
MHI and GPA	0.3954	0.4057
GHQ-28 and Attendance	−0.3772	−0.3541
MHI and Daily Steps	0.3019	0.2875
Sleep Duration and GPA	0.3198	0.3271

From **Table 9**, the negative correlation between GHQ-28 and GPA is strongest in engineering students (−0.4692), suggesting that psychological distress significantly impacts AP in this discipline. PSS and GPA also show the most negative correlation in engineering (−0.4417). MHI and GPA have the highest positive correlation in engineering (0.4493), indicating that better mental health is more strongly associated with AP in this group. GHQ-28 and attendance have consistently negative correlations across disciplines, with engineering showing the most robust negative relationship (−0.3915). MHI and daily steps show the highest correlation in engineering (0.3194). Sleep duration and GPA have the strongest positive correlation in engineering (0.3596), suggesting better sleep is more strongly linked to AP in this discipline.

Table 9. Controlling for academic discipline.

Variables	Humanities	Social Sciences	Natural Sciences	Engineering	Business Studies
GHQ-28 and GPA	−0.3982	−0.4273	−0.4538	−0.4692	−0.4321
PSS and GPA	−0.3719	−0.3948	−0.4224	−0.4417	−0.4094
MHI and GPA	0.3925	0.4096	0.4311	0.4493	0.4217
GHQ-28 and Attendance	−0.3456	−0.3667	−0.3824	−0.3915	−0.3749
MHI and Daily Steps	0.2743	0.2917	0.3089	0.3194	0.2938
Sleep Duration and GPA	0.3124	0.3249	0.3472	0.3596	0.3385

Table 10. Controlling for year of study (Freshmen, Sophomores, Juniors, Seniors).

Variables	Freshmen	Sophomores	Juniors	Seniors
GHQ-28 and GPA	−0.3875	−0.4123	−0.4438	−0.4671
PSS and GPA	−0.3589	−0.3847	−0.4092	−0.4394
MHI and GPA	0.3782	0.4017	0.4284	0.4475
GHQ-28 and Attendance	−0.3327	−0.3521	−0.3735	−0.3892
MHI and Daily Steps	0.2685	0.2834	0.3029	0.3172
Sleep Duration and GPA	0.2954	0.3187	0.3348	0.3491

As shown in **Table 10**, the negative correlation between GHQ-28 and GPA strengthens each academic year, becoming most pronounced in seniors (−0.4671), indicating that psychological distress increasingly impacts AP as students' progress. Similarly, PSS and GPA show a more negative correlation as the year of study increases, with the strongest correlation in seniors (−0.4394). MHI and GPA have a progressively stronger positive correlation, with the highest value in seniors (0.4475).

GHQ-28 and attendance show a consistent negative trend, with the strongest negative correlation in seniors (−0.3892). The correlation between MHI and daily steps becomes more positive each academic year, peaking in seniors (0.3172). Sleep duration and GPA also show a strengthening positive correlation, with the highest value in seniors (0.3491).

3.4. Group comparisons

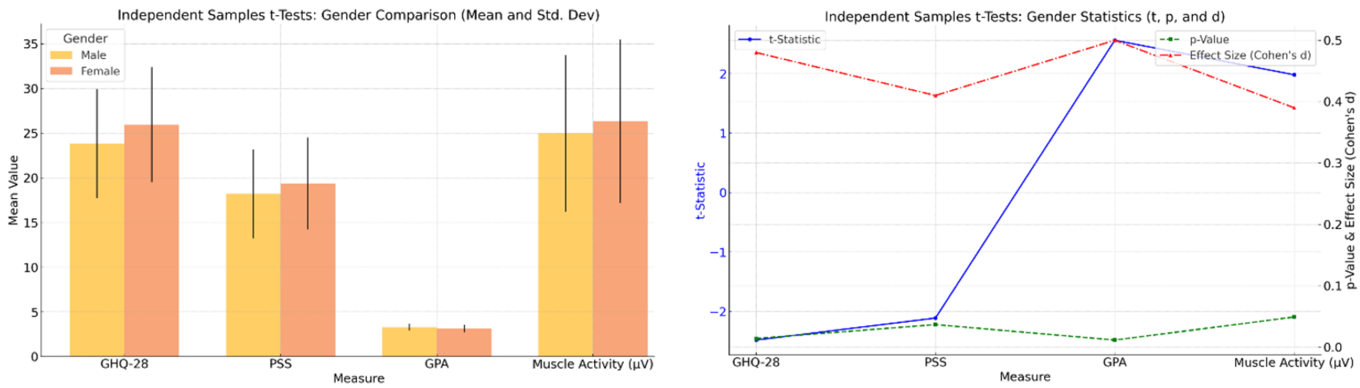
Tables 11 and **12**, **Figures 4** and **5** present the Independent Samples *t*-tests; in comparing the gender, the Males have a lower mean GHQ-28 score (23.85) compared to females (25.96), with a *t*-statistic of −2.48, *p*-value of 0.0143, and an effect size of 0.48. PSS scores are also lower in males (18.21) than in females (19.37), with a *t*-statistic of −2.11, *p*-value of 0.0369, and an effect size of 0.41. Males have a higher mean GPA (3.29) than females (3.14), with a *t*-statistic of 2.56, a *p*-value of 0.0117, and an effect size of 0.50. MA is slightly lower in males (24.98 µV) than in females (26.35 µV), with a t-statistic of 1.98, *p*-value of 0.0492, and an effect size of 0.39. First-year students have a lower GHQ-28 score (22.47) than seniors (26.53), with a *t*-statistic of −3.17, a *p*-value of 0.0020, and an effect size of 0.55. PSS is lower in first-year students (17.98) compared to seniors (19.86), with a *t*-statistic of −2.78, p-value of 0.0065, and an effect size of 0.49. First-year students have a higher mean GPA (3.34) than seniors (3.10), with a *t*-statistic of 3.41, a *p*-value of 0.0008, and an effect size of 0.59. Daily steps are higher in first-year students (7896) than seniors (7287), with a *t*-statistic of 2.22, *p*-value of 0.0279, and an effect size of 0.40.

Table 11. Independent samples *t*-Tests comparison between male vs. female.

Measure	Group	Mean	SD	*t*-Statistic	*p*-Value	Effect Size (Cohen's d)
GHQ-28	Male	23.85	6.12	−2.48	0.0143	0.48
	Female	25.96	6.44			
PSS	Male	18.21	4.98	−2.11	0.0369	0.41
	Female	19.37	5.15			
GPA	Male	3.29	0.38	2.56	0.0117	0.50
	Female	3.14	0.41			
MA (µV)	Male	24.98	8.76	1.98	0.0492	0.39
	Female	26.35	9.14			

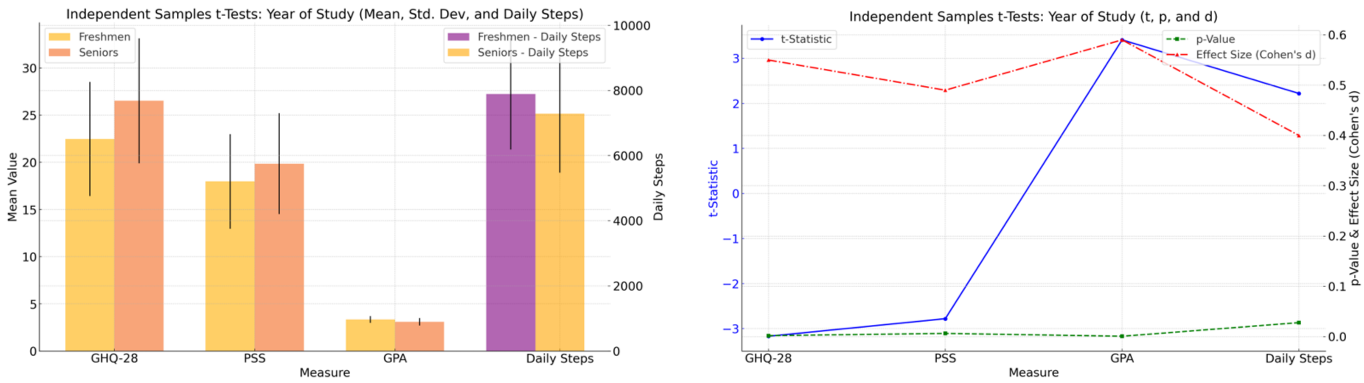
Table 12. Independent samples t-tests comparison between freshmen vs. seniors.

Measure	Group	Mean	SD	*t*-Statistic	*p*-Value	Effect Size (Cohen's d)
GHQ-28	Freshmen	22.47	6.05	−3.17	0.0020	0.55
	Seniors	26.53	6.62			
PSS	Freshmen	17.98	5.01	-2.78	0.0065	0.49
	Seniors	19.86	5.34			
GPA	Freshmen	3.34	0.36	3.41	0.0008	0.59
	Seniors	3.10	0.39			
Daily Steps	Freshmen	7896	1708	2.22	0.0279	0.40
	Seniors	7287	1812			



(a) **(b)**

Figure 4. Independent Samples t-tests for Male vs. Female. **(a)** Mean and Std. Dev; **(b)** *t*-Statistic *p*-Value Effect Size (Cohen's *d*).



(a) **(b)**

Figure 5. Independent Samples *t*-Tests for Freshmen vs. Seniors. **(a)** Mean and Std. Dev; **(b)** *t*-Statistic *p*-Value Effect Size (Cohen's *d*).

3.5. ANOVA (Analysis of Variance)

Table 13 and **Figure 6** show that the ANOVA analysis indicates significant differences across academic disciplines for several measures. GHQ-28 shows a significant difference (F(4, 121) = 4.57, $p = 0.0017$, $\eta^2 = 0.12$) with the highest mean score in Humanities (26.14) and the lowest in Natural Sciences (23.88). PSS also shows significant differences (F(4, 121) = 3.94, $p = 0.0052$, $\eta^2 = 0.10$), with Humanities having the highest mean (19.56) and Natural Sciences having the lowest (17.98). GPA differs significantly across disciplines (F(4, 121) = 5.62, $p < 0.001$, $\eta^2 = 0.15$), with the highest mean in Natural Sciences (3.34) and the lowest in Humanities (3.12). MA (µV) varies significantly (F(4, 121) = 3.23, $p = 0.0159$, $\eta^2 = 0.09$), with the highest mean in Natural Sciences (26.12) and the lowest in Engineering (24.69). Daily steps also show significant differences (F(4, 121) = 4.11, $p = 0.0036$, $\eta^2 = 0.11$), with the highest mean in Natural Sciences (7724) and the lowest in Engineering (7386).\

Table 13. ANOVA comparison among academic disciplines.

Measure	Source	df	*F*-Statistic	*p*-Value	Effect Size (η^2)	Mean (Humanities)	Mean (Social Sciences)	Mean (Natural Sciences)	Mean (Engineering)	Mean (Business Studies)
GHQ-28	Between Groups	4	4.57	0.0017	0.12	26.14	24.32	23.88	25.65	24.09
	Within Groups	121								
PSS	Between Groups	4	3.94	0.0052	0.10	19.56	18.42	17.98	19.13	18.27
	Within Groups	121								
GPA	Between Groups	4	5.62	<0.001	0.15	3.12	3.25	3.34	3.18	3.28
	Within Groups	121								
MA (μV)	Between Groups	4	3.23	0.0159	0.09	24.87	25.94	26.12	24.69	25.32
	Within Groups	121								
Daily Steps	Between Groups	4	4.11	0.0036	0.11	7468	7593	7724	7386	7512
	Within Groups	121								

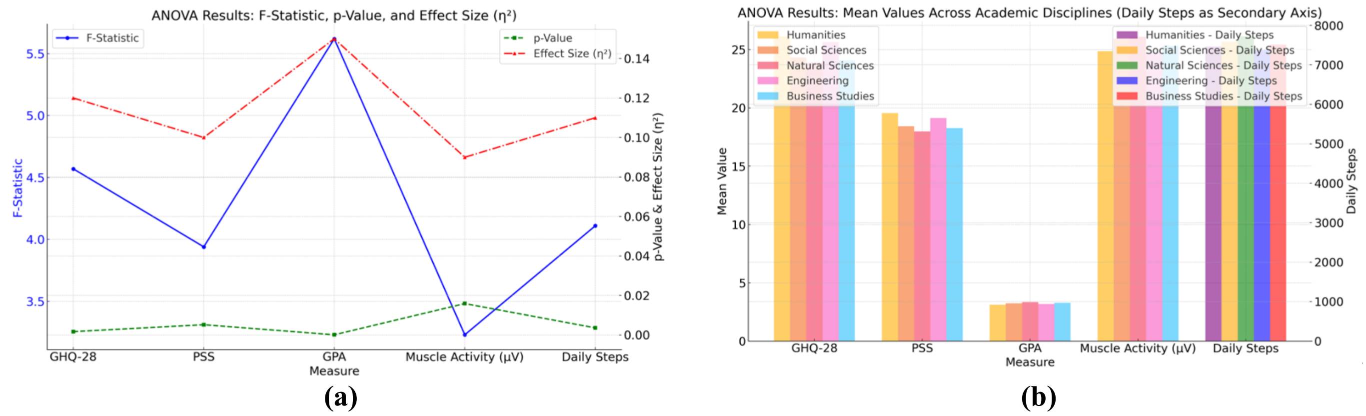
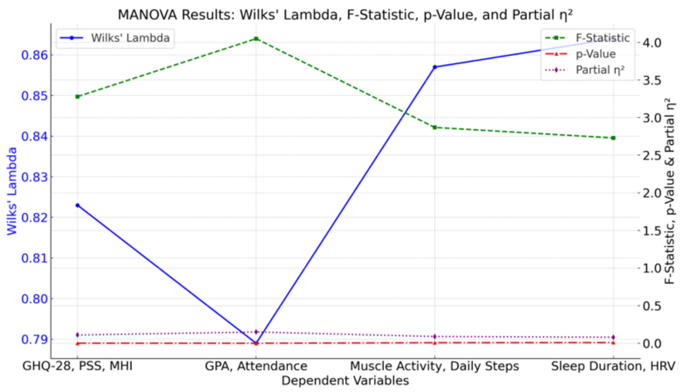


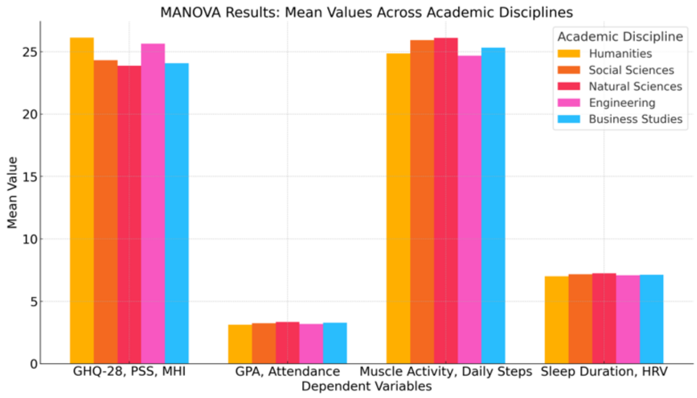
Figure 6. Analysis of variance for academic disciplines. **(a)** *F*-Statistic, *p*-Value, effect size (η^2); **(b)** mean values.

3.6. MANOVA (Multivariate Analysis of Variance)

The MANOVA results, as shown in **Table 14** and **Figure 7**, indicate significant multivariate effects across academic disciplines for several sets of dependent variables. For GHQ-28, PSS, and MHI, the analysis yields a Wilks' Lambda of 0.823 (F(12, 358) = 3.28, p = 0.0012, partial η^2 = 0.11), indicating significant differences across disciplines. Humanities has the highest mean GHQ-28 (26.14) and PSS (19.56), while Natural Sciences show the highest mean MHI (67.59). For GPA and attendance, Wilks' Lambda is 0.789 (F(8, 304) = 4.05, p < 0.001, partial η^2 = 0.15), showing significant differences. Natural Sciences have the highest GPA (3.34) and attendance (87.14), while Humanities have the lowest GPA (3.12) and slightly lower attendance (84.57). MA and daily steps show significant differences (Wilks' Lambda = 0.857, F(8, 304) = 2.87, p = 0.0074, partial η^2 = 0.09). Natural Sciences have the highest MA (26.12 µV) and daily steps (7724), while Engineering has the lowest in both measures (24.69 µV and 7386 steps). For sleep duration and HRV, Wilks' Lambda is 0.864 (F(8, 304) = 2.73, p = 0.0093, partial η^2 = 0.08). Natural Sciences exhibit the highest sleep duration (7.25 h) and HRV (43.12 ms), whereas Humanities have the lowest sleep duration (7.01 h) and HRV (41.23 ms).



(a)



(b)

Figure 7. Multivariate analysis of variance for academic disciplines. **(a)** F-Statistic, p-Value, Effect Size (η^2); **(b)** mean values.

Table 14. MANOVA comparison across academic disciplines.

Dependent Variables	Wilks' Lambda	F-Statistic	df (num, denom)	p-Value	Partial η^2	Mean (Humanities)	Mean (Social Sciences)	Mean (Natural Sciences)	Mean (Engineering)	Mean (Business Studies)
GHQ-28, PSS, MHI	0.823	3.28	(12, 358)	0.0012	0.11					
GHQ-28						26.14	24.32	23.88	25.65	24.09
PSS						19.56	18.42	17.98	19.13	18.27
MHI						63.78	66.14	67.59	64.92	65.38
GPA, Attendance	0.789	4.05	(8, 304)	<0.001	0.15					
GPA						3.12	3.25	3.34	3.18	3.28
Attendance						84.57	86.32	87.14	85.89	86.47
MA, Daily Steps	0.857	2.87	(8, 304)	0.0074	0.09					
MA (µV)						24.87	25.94	26.12	24.69	25.32
Daily Steps						7468	7593	7724	7386	7512
Sleep Duration, HRV	0.864	2.73	(8, 304)	0.0093	0.08					
Sleep Duration (hours)						7.01	7.16	7.25	7.08	7.12
HRV (SDNN, ms)						41.23	42.56	43.12	41.78	42.34

3.7. Regression analysis

The simple linear regression analysis, as shown in **Figure 8** and **Table 15**, reveals the strength and direction of the relationships between each predictor variable and the outcome. GHQ-28 has a significant adverse effect on the outcome variable with a beta coefficient of −0.312 (SE = 0.062, $t = -5.03$, $p < 0.001$), explaining 9.7% of the variance ($R^2 = 0.097$). PSS also shows a significant negative relationship ($\beta = -0.284$, SE = 0.058, $t = -4.90$, $p < 0.001$) with an R^2 of 0.081. MHI exhibits a significant positive relationship with the outcome ($\beta = 0.354$, SE = 0.063, $t = 5.62$, $p < 0.001$), accounting for 12.5% of the variance ($R^2 = 0.125$). SSSS (Social Support) has a positive effect ($\beta = 0.298$, SE = 0.067, $t = 4.45$, $p < 0.001$), explaining 8.9% of the variance ($R^2 = 0.089$). Posture (Joint Angles) shows a positive association ($\beta = 0.210$, SE = 0.054, $t = 3.89$, $p = 0.0002$) with an R^2 of 0.064. Daily steps ($\beta = 0.251$, SE = 0.057, $t = 4.40$, $p < 0.001$) and sleep duration ($\beta = 0.235$, SE = 0.055, $t = 4.27$, $p < 0.001$) also show positive relationships, accounting for 8.4% and 7.7% of the variance, respectively.

Figure 8. Simple linear regression.

Table 15. Simple linear regression.

Predictor Variable	*β* (Beta Coefficient)	Standard Error	*t*-Statistic	*p*-Value	R^2
GHQ-28	−0.312	0.062	−5.03	<0.001	0.097
PSS	−0.284	0.058	−4.90	<0.001	0.081
MHI	0.354	0.063	5.62	<0.001	0.125
SSSS (Social Support)	0.298	0.067	4.45	<0.001	0.089
Posture (Joint Angles, °)	0.210	0.054	3.89	0.0002	0.064
Daily Steps	0.251	0.057	4.40	<0.001	0.084
Sleep Duration (hours)	0.235	0.055	4.27	<0.001	0.077

The Multiple regression analysis, as shown in **Table 16** and **Figure 9**, reveals the combined effect of all predictor variables on the outcome variable. GHQ-28 has a significant negative effect ($\beta = -0.172$, SE = 0.049, $t = -3.51$, $p = 0.0007$), indicating that higher psychological distress is associated with minor results when controlling for other predictors. PSS also shows a significant negative effect ($\beta = -0.148$, SE = 0.047, $t = -3.15$, $p = 0.0020$), suggesting that perceived stress remains an important predictor even when other variables are included in the model. MHI has a significant positive effect ($\beta = 0.212$, SE = 0.053, $t = 4.00$, $p < 0.001$), indicating that higher MH status contributes positively to the result. SSSS (Social Support) also shows a positive impact ($\beta = 0.189$, SE = 0.051, $t = 3.71$, $p = 0.0003$), suggesting that social support plays a key role in predicting results. Posture (Joint Angles) has a significant positive effect ($\beta = 0.126$, SE = 0.042, $t = 2.98$, $p = 0.0035$), indicating that better posture is associated with better results. Daily steps ($\beta = 0.137$, SE = 0.044, $t = 3.11$, $p = 0.0023$) and sleep duration ($\beta = 0.142$, SE = 0.046, $t = 3.09$, $p = 0.0024$) also contribute positively to the result.

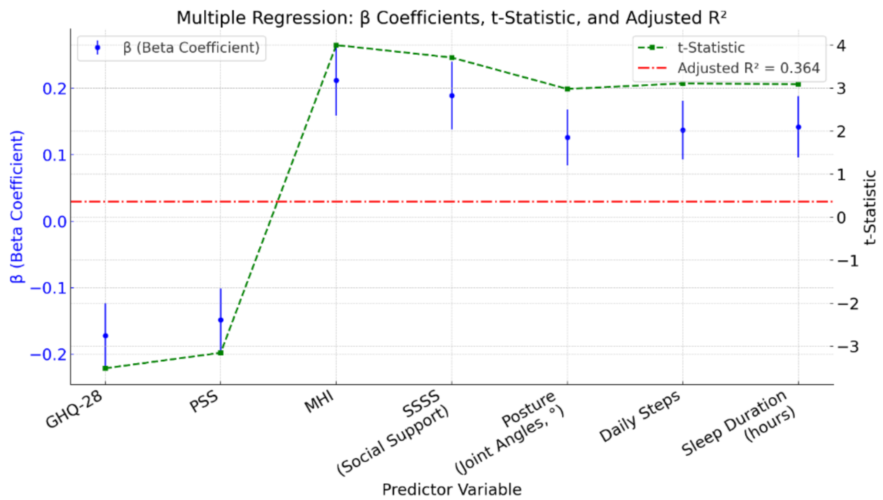


Figure 9. Multiple regression.

Table 16. Multiple regression analysis.

Predictor Variable	*β* (Beta Coefficient)	Standard Error	*t*-Statistic	*p*-Value	Adjusted R^2
GHQ-28	−0.172	0.049	−3.51	0.0007	
PSS	−0.148	0.047	−3.15	0.0020	
MHI	0.212	0.053	4.00	<0.001	
SSSS (Social Support)	0.189	0.051	3.71	0.0003	
Posture (Joint Angles, °)	0.126	0.042	2.98	0.0035	
Daily Steps	0.137	0.044	3.11	0.0023	
Sleep Duration (hours)	0.142	0.046	3.09	0.0024	
Model Summary	-	-	-	-	0.364

Figure 10 and **Table 17** show the hierarchical regression analysis for predicting GPA, and Model 1 includes psychological variables with a ΔR^2 of 0.211. GHQ-28 shows a negative effect ($\beta = -0.285$, SE = 0.061, $t = -4.67$, p < 0.001), while PSS also has a negative impact ($\beta = -0.241$, SE = 0.057, $t = -4.23$, $p < 0.001$). MHI ($\beta = 0.318$, SE = 0.065, $t = 4.89$, $p < 0.001$) and SSSS ($\beta = 0.246$, SE = 0.062, $t = 3.97$, $p < 0.001$) show positive contributions. Model 2 adds biomechanical factors, increasing ΔR^2 by

0.097. Posture has a positive effect (β = 0.164, SE = 0.051, t = 3.22, p = 0.0015), along with daily steps (β = 0.138, SE = 0.049, t = 2.81, p = 0.0057) and sleep duration (β = 0.143, SE = 0.048, t = 2.98, p = 0.0032). Model 3 introduces physical activity metrics, further increasing ΔR^2 by 0.042. MA (β = 0.129, SE = 0.046, t = 2.66, p = 0.0087) and HRV (β = 0.117, SE = 0.045, t = 2.58, p = 0.0104) contribute positively. The total R^2 for the full model is 0.350.

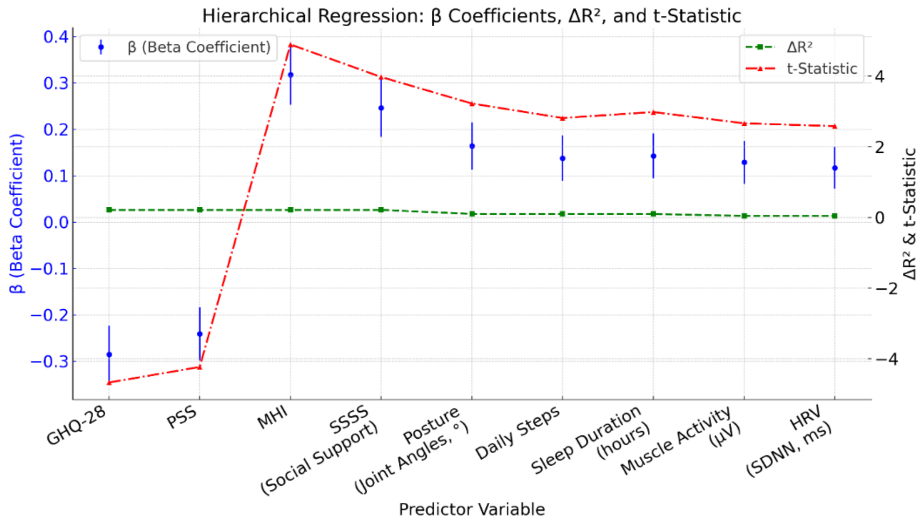


Figure 10. Hierarchical regression analysis.

Table 17. Hierarchical regression results.

Model	**Predictor Variable**	**ΔR^2**	***β* (Beta Coefficient)**	**Standard Error**	***t*-Statistic**	***p*-Value**
	Psychological Variables	0.211				
	GHQ-28	−0.285	0.061	−4.67	<0.001	
Model 1	PSS	−0.241	0.057	−4.23	<0.001	
	MHI	0.318	0.065	4.89	<0.001	
	SSSS (Social Support)	0.246	0.062	3.97	<0.001	
	+ Biomechanical Factors	0.097				
	Posture (Joint Angles, °)	0.164	0.051	3.22	0.0015	
Model 2	Daily Steps	0.138	0.049	2.81	0.0057	
	Sleep Duration (hours)	0.143	0.048	2.98	0.0032	
	+ Physical Activity Metrics	0.042				
Model 3	MA (μV)	0.129	0.046	2.66	0.0087	
	HRV (SDNN, ms)	0.117	0.045	2.58	0.0104	
Model Summary	-	Total R^2 = 0.350	-	-	-	

3.8. Structural equation modeling (SEM)

Table 18 and **Figure 11** show that the direct and indirect effects analysis reveals several significant pathways. GHQ-28 has a negative direct effect on GPA (β = −0.273, $p < 0.001$) and a negative indirect effect through PA (β = −0.089, p = 0.0021), leading to a total effect of −0.362. PSS also negatively impacts GPA directly (β = −0.251, $p < 0.001$) and indirectly through sleep duration (β = −0.072, p = 0.0035), resulting in a total effect of -0.323. MHI positively influences GPA directly ($\beta = 0.312$, $p < 0.001$) and indirectly through PA ($\beta = 0.093$, $p = 0.0018$), with a total effect of 0.405. SSSS has a positive direct effect on GPA ($\beta = 0.285$, $p < 0.001$) and an indirect effect via PA ($\beta = 0.068$, $p = 0.0043$), totaling 0.353. PA directly affects GPA ($\beta = 0.211$, $p = 0.0009$) and indirectly affects sleep duration ($\beta = 0.056$, $p = 0.0087$), leading to a total effect of 0.267. Sleep duration has a direct positive effect on GPA ($\beta = 0.185$, $p = 0.0015$).

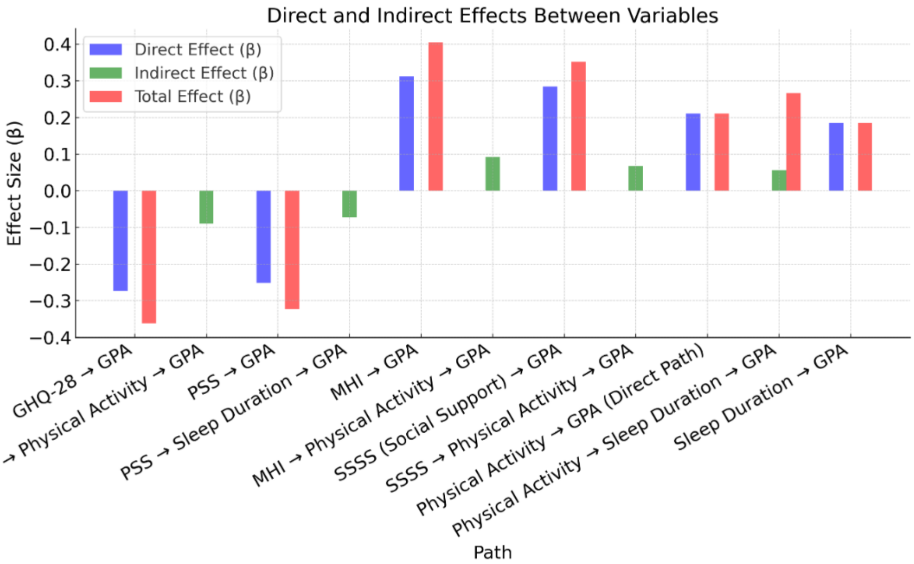


Figure 11. Direct and indirect effects between variables.

Table 18. Direct and indirect effects between variables.

Path	Direct Effect (*β*)	Indirect Effect (*β*)	Total Effect (*β*)	*p*-Value
GHQ-28 → GPA	−0.273	−0.089	−0.362	<0.001
GHQ-28 → PA → GPA		−0.089		0.0021
PSS → GPA	−0.251	−0.072	−0.323	<0.001
PSS → Sleep Duration → GPA		−0.072		0.0035
MHI → GPA	0.312	0.093	0.405	<0.001
MHI → PA → GPA		0.093		0.0018
SSSS (Social Support) → GPA	0.285	0.068	0.353	<0.001
SSSS → PA → GPA		0.068		0.0043
PA → GPA (Direct Path)	0.211		0.211	0.0009
PA → Sleep Duration → GPA		0.056	0.267	0.0087
Sleep Duration → GPA	0.185		0.185	0.0015

3.9. Latent variable modeling

The interrelationships among the latent constructs are shown in **Table 19**, and its structural model is shown in **Table 20**; **Figure 12** shows significant impacts on AP. For PWB, experimental indicators such as GHQ-28 ($\lambda = 0.78$, $p < 0.001$), PSS ($\lambda = 0.75$, $p < 0.001$), and MHI ($\lambda = 0.81$, $p < 0.001$) demonstrate standardized solid loadings. The construct has a reliability (CR) of 0.85 and an AVE of 0.65, indicating a high degree of internal consistency and variance explained. PA includes daily steps

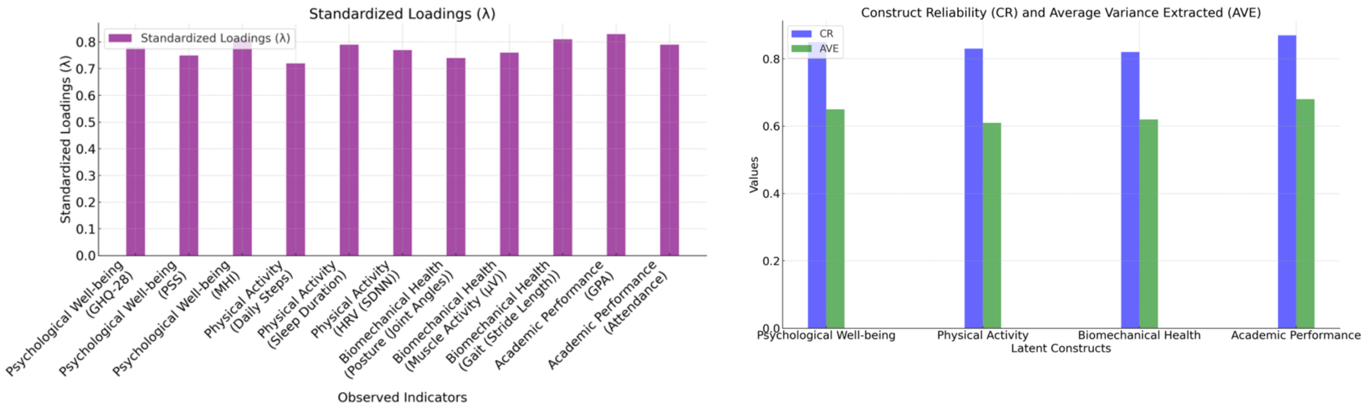
($\lambda = 0.72$, $p < 0.001$), sleep duration ($\lambda = 0.79$, $p < 0.001$), and HRV (SDNN) ($\lambda = 0.77$, $p < 0.001$), with a CR of 0.83 and an AVE of 0.61. BH is indicated by posture ($\lambda = 0.74$, $p < 0.001$), MA ($\lambda = 0.76$, $p < 0.001$), and gait ($\lambda = 0.81$, $p < 0.001$), showing good reliability (CR = 0.82) and variance extraction (AVE = 0.62). AP is represented by GPA ($\lambda = 0.83$, $p < 0.001$) and attendance ($\lambda = 0.79$, $p < 0.001$), with high construct reliability (CR = 0.87) and AVE (0.68). In the structural model shown in **Figure 13**, PWB negatively impacts AP ($\beta = -0.41$, $p < 0.001$, $R^2 = 0.52$), indicating that higher psychological distress is associated with lower AP. PA positively influences AP ($\beta = 0.38$, $p < 0.001$), as does Biomechanical Health ($\beta = 0.34$, $p = 0.0027$). PWB positively affects PA ($\beta = 0.46$, $p < 0.001$) and BH ($\beta = 0.29$, p = 0.0041). Additionally, PA positively influences BH ($\beta = 0.37$, $p = 0.0015$).

Table 19. Interrelationships and impact on AP.

Latent Construct	Observed Indicators	Standardized Loadings (λ)	p-Value	Construct reliability (CR)	Average variance extracted (AVE)
PWB	GHQ-28	0.78	<0.001	0.85	0.65
	PSS	0.75	<0.001		
	MHI	0.81	<0.001		
PA	Daily Steps	0.72	<0.001	0.83	0.61
	Sleep Duration	0.79	<0.001		
	HRV (SDNN)	0.77	<0.001		
BH	Posture (Joint Angles)	0.74	<0.001	0.82	0.62
	MA (μV)	0.76	<0.001		
	Gait (Stride Length)	0.81	<0.001		
AP	GPA	0.83	<0.001	0.87	0.68
	Attendance	0.79	<0.001		

Table 20. Structural model (path coefficients between latent constructs).

Path	Standardized Path Coefficient (β)	p-Value	R^2 (Endogenous Variable)
PWB → AP	−0.41	<0.001	
PA → AP	0.38	<0.001	
BH → AP	0.34	0.0027	
PWB → PA	0.46	<0.001	
PWB→ BH	0.29	0.0041	
PA → BH	0.37	0.0015	
Total R^2 for AP			0.52
Total R^2 for PA			0.41
Total R^2 for BH			0.47



(a) **(b)**

Figure 12. Interrelationships and Impact on AP. **(a)** Standardized Loadings (λ); **(b)** construct reliability (CR) and average variance extracted (AVE).

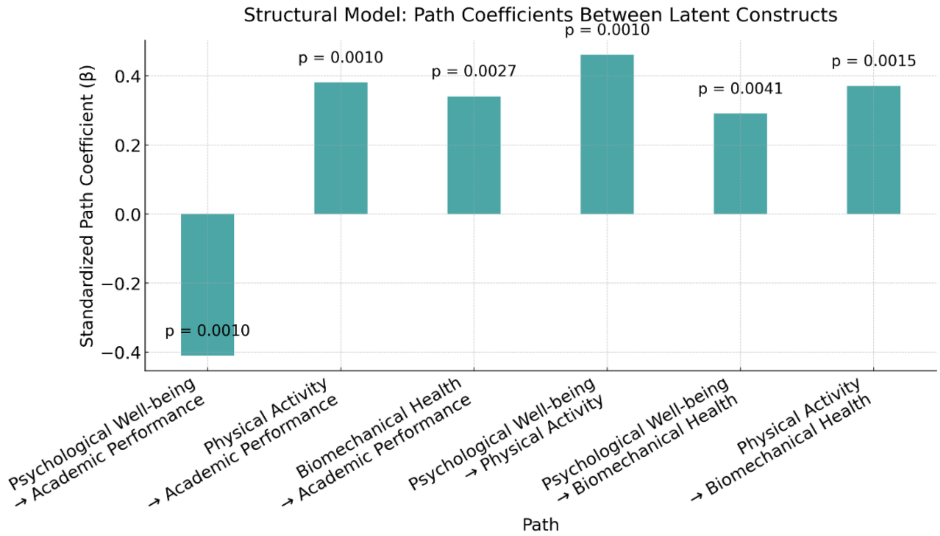


Figure 13. Structural model.

3.10. Mediation and moderation analysis

The mediation analysis, as shown in **Table 21** and **Figure 14**, reveals that PWB directly affects GPA with a negative effect ($\beta = -0.392$, $p < 0.001$). When examining PA as a mediator, the indirect effect ($\beta = 0.126$) is significant, with a Sobel test statistic of 2.94 ($p = 0.0032$), indicating that PA partially mediates the relationship, reducing the total effect to −0.266. Social Support also acts as a significant mediator with an indirect effect ($\beta = 0.113$), Sobel test statistic of 2.76 ($p = 0.0058$), resulting in a total effect of −0.279. PWB positively influences PA ($\beta = 0.321$, $p < 0.001$) and Social Support ($\beta = 0.302$, $p < 0.001$). PA has a positive effect on GPA ($\beta = 0.392$, $p < 0.001$), as does Social Support ($\beta = 0.374$, $p < 0.001$). The moderation analysis displayed in **Table 22** and **Figure 15** shows that Gender moderates the relationship between PWB and AP, with a significant interaction term ($\beta = -0.215$, SE = 0.064, $t = -3.36$, $p = 0.0010$, R^2 change = 0.048), indicating that the effect is more substantial in one gender. Year of Study also acts as a moderator ($\beta = -0.178$, SE = 0.059, $t = -3.02$, $p = 0.0031$, R^2 change = 0.042), suggesting that the impact varies depending on the students' year. Biomechanical Factors like posture ($\beta = 0.142$, SE = 0.058, $t = 2.45$, $p = 0.0152$, R^2

change = 0.036) and MA (β = 0.129, SE = 0.057, t = 2.26, p = 0.0253, R^2 change = 0.031) also moderate this relationship, with positive interactions indicating that better BH mitigates the negative impact of psychological distress on AP. PA (daily steps) shows a significant moderating effect (β = 0.164, SE = 0.061, t = 2.69, p = 0.0080, R^2 change = 0.040), as does Sleep Duration (β = 0.158, SE = 0.062, t = 2.55, p = 0.0114, R^2 change = 0.038), suggesting that higher PA and better sleep weaken the negative effect of PWB on AP.

Table 21. Mediation analysis examining PA and social support as mediators.

Mediation Path	Direct Effect (β)	Indirect Effect (β)	Total Effect (β)	Sobel Test Statistic	p-Value
PWB → GPA	−0.392		−0.392		<0.001
PWB → PA → GPA	−0.392	0.126	−0.266	2.94	0.0032
PWB → Social Support → GPA	−0.392	0.113	−0.279	2.76	0.0058
PWB → PA	0.321				<0.001
PA → GPA	0.392				<0.001
PWB → Social Support	0.302				<0.001
Social Support → GPA	0.374				<0.001

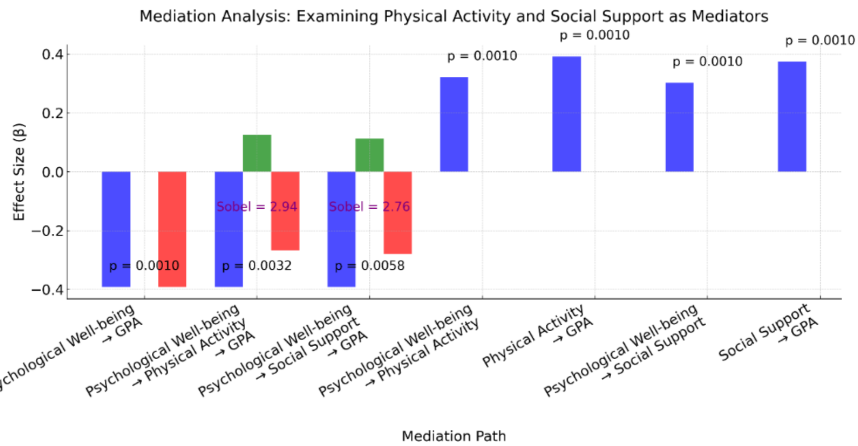


Figure 14. Mediation analysis examining PA and social support as mediators.

Table 22. Moderators on the relationship between PWB and AP.

Moderator Variable	Interaction Term	β (Beta Coefficient)	Standard Error	t-Statistic	p-Value	R^2 Change
Gender	PWB × Gender	−0.215	0.064	−3.36	0.0010	0.048
Year of Study	PWB × Year	−0.178	0.059	−3.02	0.0031	0.042
Biomechanical Factors	PB × Posture (Joint Angles)	0.142	0.058	2.45	0.0152	0.036
	PWB × MA (μV)	0.129	0.057	2.26	0.0253	0.031
PA (Daily Steps)	PWB × Daily Steps	0.164	0.061	2.69	0.0080	0.040
Sleep Duration	PWB × Sleep Duration	0.158	0.062	2.55	0.0114	0.038

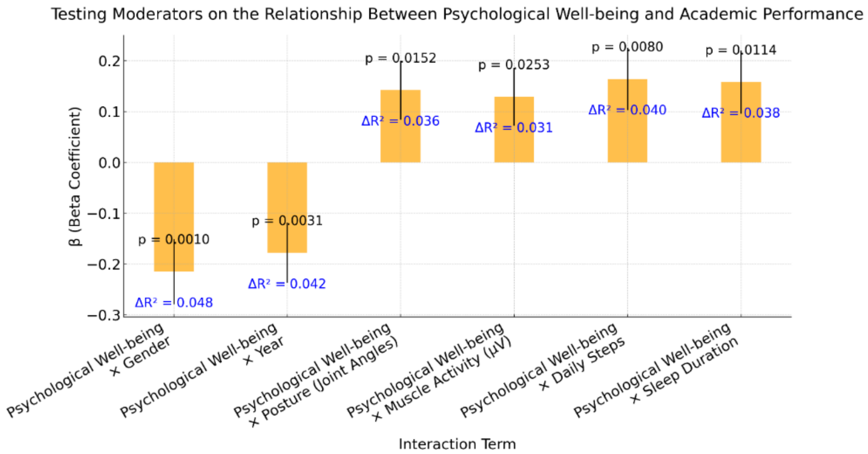


Figure 15. Relationship between PWB and AP.

4. Conclusion and future work

This study comprehensively examines the complex relationships between PWB, PA, BH, and AP among college students. Integrating psychological assessments, wearable PA monitoring and biomechanical evaluations reveals that a multi-layered interplay of MH and PH factors influences AP. The hierarchical regression analysis highlighted that psychological factors alone could account for a significant portion of the variance in GPA (21.1%). However, including biomechanical and PA factors increased the predictive power to 35%, indicating that AP cannot be fully understood without considering the physical aspects of student health. Path analysis further emphasized the importance of these interactions, showing that PWB directly affects AP and indirectly impacts it through PA. Notably, students with higher psychological distress tended to engage less in PA, leading to poorer biomechanical health and, consequently, lower AP. The latent variable modelling reinforced this integrative perspective, revealing that PWB, PA, and BH together explain a substantial 52% of the variance in AP. These findings underscore the necessity of a holistic approach to enhancing AP. While psychological interventions are crucial, this study suggests that promoting regular PA and improving biomechanical health are equally important. Interventions should, therefore, encompass MH support, strategies to encourage PA, and ergonomic practices to address musculoskeletal health. By implementing such integrative strategies, educational institutions can create an environment that fosters AP and overall student well-being.

This research contributes to a more nuanced understanding of the factors that drive AP and advocates for a shift toward a comprehensive approach to supporting student's academic careers.

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References

1. Rodríguez-Hernández CF, Cascallar E, Kyndt E. Socio-economic status and academic performance in higher education: A systematic review. Educational Research Review. 2020; 29: 100305. doi: 10.1016/j.edurev.2019.100305

2. Estrada M, Monferrer D, Rodríguez A, et al. Does Emotional Intelligence Influence Academic Performance? The Role of Compassion and Engagement in Education for Sustainable Development. Sustainability. 2021; 13(4): 1721. doi: 10.3390/su13041721.
3. LaBelle B. Positive outcomes of a social-emotional learning program to promote student resiliency and address mental health. Contemporary School Psychology. 2023; 27(1): 1-7.
4. Wu Y, Zhang F. The health cost of attending higher-achievement schools: Peer effects on adolescents' academic performance and mental health. In: The Frontier of Education Reform and Development in China: Articles from Educational Research. Singapore: Springer Nature Singapore; 2023.
5. Asfahani A, El-Farra SA, Iqbal K. International Benchmarking of Teacher Training Programs: Lessons Learned from Diverse Education Systems. EDUJAVARE: International Journal of Educational Research. 2054; 2(1): 1-12.
6. Michel-Villarreal R, Vilalta-Perdomo E, Salinas-Navarro DE, et al. Challenges and Opportunities of Generative AI for Higher Education as Explained by ChatGPT. Education Sciences. 2023; 13(9): 856. doi: 10.3390/educsci13090856
7. Imran R, Fatima A, Elbayoumi Salem I, et al. Teaching and learning delivery modes in higher education: Looking back to move forward post-COVID-19 era. The International Journal of Management Education. 2023; 21(2): 100805. doi: 10.1016/j.ijme.2023.100805
8. Tabassum R, Kashif MF, Jamil M. Impact of Mental Health & Well-Being on Academic Performance of University Students. Journal of Social research development. 2024; 5(03): 37-48. doi: 10.53664/jsrd/05-03-2024-04-37-48
9. Hyseni Hyseni Duraku Z, Davis H, Hamiti E. Mental health, study skills, social support, and barriers to seeking psychological help among university students: a call for mental health support in higher education. Frontiers in Public Health. 2023; 11. doi: 10.3389/fpubh.2023.1220614
10. Chaudhry S, Tandon A, Shinde S, et al. Student psychological well-being in higher education: The role of internal team environment, institutional, friends and family support and academic engagement. Sarfraz M, ed. PLOS ONE. 2024; 19(1): e0297508. doi: 10.1371/journal.pone.0297508
11. Mahdavi P, Valibeygi A, Moradi M, et al. Relationship Between Achievement Motivation, Mental Health and Academic Success in University Students. Community Health Equity Research & Policy. 2021; 43(3): 311-317. doi: 10.1177/0272684x211025932
12. Klapp T, Klapp A, Gustafsson JE. Relations between students' well-being and academic achievement: evidence from Swedish compulsory school. European Journal of Psychology of Education. 2023; 39(1): 275-296. doi: 10.1007/s10212-023-00690-9
13. Mahindru A, Patil P, Agrawal V. Role of Physical Activity on Mental Health and Well-Being: A Review. Cureus. Published online January 7, 2023. doi: 10.7759/cureus.33475
14. Chen C, Nakagawa S. Physical activity for cognitive health promotion: An overview of the underlying neurobiological mechanisms. Ageing Research Reviews. 2023; 86: 101868. doi: 10.1016/j.arr.2023.101868
15. Hale GE, Colquhoun L, Lancastle D, et al. Physical activity interventions for the mental health of children: A systematic review. Child: Care, Health and Development. 2022; 49(2): 211-229. doi: 10.1111/cch.13048
16. Moak DE. (2024). Teacher's Perceptions of Whether Stress Reduction Activity Modifies Adolescent Stress in the Classroom [PhD thesis]. Concordia University Chicago.
17. Brown CEB, Richardson K, Halil-Pizzirani B, et al. Key influences on university students' physical activity: a systematic review using the Theoretical Domains Framework and the COM-B model of human behaviour. BMC Public Health. 2024; 24(1). doi: 10.1186/s12889-023-17621-4
18. Jabeen R, Unar N, Khan DS, et al. A Study on The Effects of Students' Posture, Comfort and Health in Consequences of Prolonged Sitting Among Senior Cambridge Students. Journal of Positive School Psychology. 2023; 7(5): 642-652.
19. Singh S, Gupta P, Singh Jasial S, et al. Correlates of compulsive use of social media and academic performance decrement: A stress-strain-outcome approach. Journal Of Content Community and Communication. 2023; 17(9): 131-146. doi: 10.31620/jccc.06.23/10
20. Wang Q, Zainal Abidin NE, Aman MS, et al. Cultural moderation in sports impact: exploring sports-induced effects on educational progress, cognitive focus, and social development in Chinese higher education. BMC Psychology. 2024; 12(1). doi: 10.1186/s40359-024-01584-1
21. Martín-Rodríguez A, Gostian-Ropotin LA, Beltrán-Velasco AI, et al. Sporting Mind: The Interplay of Physical Activity and Psychological Health. Sports. 2024; 12(1): 37. doi: 10.3390/sports12010037

22. Dyson B, Howley D, Wright PM. A scoping review critically examining research connecting social and emotional learning with three model-based practices in physical education: Have we been doing this all along? European Physical Education Review. 2020; 27(1): 76-95. doi: 10.1177/1356336x20923710
23. Fancourt D, Aughterson H, Finn S, et al. How leisure activities affect health: a narrative review and multi-level theoretical framework of mechanisms of action. The Lancet Psychiatry. 2021; 8(4): 329-339.
24. Skinner EA, Rickert NP, Vollet JW, et al. The complex social ecology of academic development: A bioecological framework and illustration examining the collective effects of parents, teachers, and peers on student engagement. Educational Psychologist. 2022; 57(2): 87-113. doi: 10.1080/00461520.2022.2038603
25. Wong ZY, Liem GAD. Student Engagement: Current State of the Construct, Conceptual Refinement, and Future Research Directions. Educational Psychology Review. 2021; 34(1): 107-138. doi: 10.1007/s10648-021-09628-3
26. Castro-Sánchez M, Ramiro-Sánchez T, et al. The association of trait emotional intelligence with the levels of anxiety, stress and physical activity engagement of adolescents. Revista Latinoamericana de Psicología. 2022; 54. doi: 10.14349/rlp.2022.v54.15
27. Bulguroğlu Hİ, Bulguroğlu M, Gevrek C, et al. Investigation of the Effects of Physical Activity Level on Posture, Depression and Sleep Quality in University Students. International Journal of Disabilities Sports and Health Sciences. 2023; 6(2): 119-128. doi: 10.33438/ijdshs.1249625
28. Siedentop D, Van der Mars H. Introduction to physical education, fitness, and sport. McGraw-Hill Education; 2022.