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Mental well-being of college students: focus on sex differences and psycho physiological indices

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Abstract

Background Questionnaires that assess psychological functioning are 21 limited by their subjective nature, while HRV can serve as a more objective 22 (but also complex) index of such functioning. This study aims to validate sex 23 differences in college students' mental well-being using psychological scales 24 and HRV, and to investigate the correlation between psychological scales 25 and HRV for each sex.

Method 240 college students (120 males and 120 females, aged 18-22 27 years) were recruited via cluster sampling from 1st Sept. to 1st Nov. 2023 at 28 Zhejiang University in China. Mental well-being was assessed using the 29 Warwick-Edinburgh Mental Well-being Scale (WEMWBS) and the 21-item 30 version of the Depression, Anxiety, and Stress Scale (DASS-21), while HRV 31 was measured at rest using a Polar H7 heart rate monitor.

Results Comparative analyses showed that female students had higher 33 anxiety scores (DASS-21) ($p = 0.033$, Partial $\eta^2 = 0.019$) and lower mental 34 well-being scores (WEMWBS) ($p = 0.047$, Partial $\eta^2 = 0.016$) compared to 35 male students. Additionally, female students exhibited lower HRV across 36 multiple indices, including SDNN ($p < 0.001$, Partial $\eta^2 = 0.158$), RMSSD (p 37 < 0.001, Partial $\eta^2 = 0.064$), pNN50 ($p < 0.001$, Partial $\eta^2 = 0.045$), and 38 absolute high-frequency (HF) power ($p = 0.003$, Partial $\eta^2 = 0.038$). 39 Correlational analyses further revealed that only female students' anxiety 40 scores were negatively associated with RMSSD ($r = -0.245$, $p = 0.008$), 41 absolute HF power ($r = -0.261$, $p = 0.005$), and normalized HF power (r = - 42 0.262, $p = 0.005$).

Conclusions Female university students exhibited poorer mental well-being 44 than male students, as indicated by both subjective and objective measures, with anxiety being particularly prominent. Combining psychological scales 46 with measures of HRV (RMSSD and HF power) may improve anxiety 47 assessment in female university students.

Keywords Anxiety, Stress, Depression, Heart rate variability, Mental well-being, Sex

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Background

According to Diener's subjective well-being model and the biopsychosocial model, well-being is a multidimensional concept encompassing subjective evaluations of life satisfaction, positive emotions, and negative emotions [1, 2]. It also reflects the interplay of biological, psychological, and social factors. Stress, anxiety, and depression are key contributors to poor mental well-being [3, 4]. In China, these issues are increasingly prevalent among college students [5]. Academic pressures, heavy workloads, lower grades, and the challenges of independent living further undermine their mental well-being [6, 7]. While most mental well-being issues emerge in early adulthood, young people often lack adequate support, increasing the risk of chronic psychological conditions and suicide [8, 9]. Therefore, sufficient attention should be paid to the mental health of university students.

Epidemiological studies have frequently reported sex differences in the prevalence of depression, anxiety, and stress [10–12]. Although systematic reviews consistently acknowledge sex differences in mental well-being, the extent of the differences in anxiety and depression symptoms remains debated [13]. For example, some cross-sectional studies have found that the observed differences in anxiety and depression between males and females do not reach statistical significance [14, 15]. This inconsistency may stem from methodological limitations, such as the predominant reliance on medical student samples and the widespread use of self-report instruments for psychological assessment [16]. Although questionnaires are widely used in clinical settings, their results are susceptible to recall bias and social expectation effects. More importantly, these subjective scales are unable to capture autonomic nervous system (ANS) dysfunction, an important pathophysiological mechanism underlying affective disorders [17, 18].

To overcome the limitations of questionnaires, recent clinical research has gradually introduced physiological measures, such as heart rate variability (HRV), into mental well-being assessments. HRV calculated from fluctuations in interbeat intervals (RR intervals), is widely used as an objective biomarker of ANS function, reflecting the dynamic balance between sympathetic and parasympathetic nervous system activity [19]. This equilibrium is regulated by the central autonomic network (CAN), a brain system that integrates emotional and cognitive processes [20]. Specifically, the CAN coordinates amygdala-mediated stress responses and prefrontal cortex-driven emotional regulation to modulate ANS activity [21]. HRV thus acts as a marker of psychological functioning through CAN-mediated regulation. Under normal conditions, balanced connectivity between the amygdala (emotion processing) and prefrontal cortex (cognitive control) maintains autonomic balance and stable HRV [22]. However, in chronic anxiety or depression, hyperactivity of the amygdala combined with weakened prefrontal control disrupts CAN connectivity, triggering sympathetic dominance and parasympathetic suppression—manifested as reduced HRV [23, 24]. This mechanism directly links HRV to the integrity of emotion-cognition integration, establishing it as a psychophysiological indicator of mental well-being.

In general, higher HRV is associated with greater emotional regulation capacity and better overall mental well-being, while lower HRV is frequently linked to higher levels of anxiety and depression [25–27]. However, this relationship is not always consistent—some studies have reported a lack of significant correlations between depression severity (e.g., Hamilton Rating Scale scores) and HRV parameters [28]. Sex differences in HRV have also received considerable research attention [29]. Meta-analyses have shown that healthy females exhibit lower SDNN and higher HF power at rest compared to males [30]. However, these sex-related differences may be influenced by experimental conditions, such as measurement duration, body posture, and environmental factors [29]. HRV is modulated by multiple demographic and methodological factors, including age, ECG recording duration and epoch length, physical activity intensity, postural changes, and circadian timing during measurement [31–34]. Therefore, applying a uniform HRV testing protocol and combining it with psychological scales can offer a more reliable and precise evaluation of sex differences in anxiety, depression, and stress from a psychophysiological perspective.

Understanding sex differences in mental well-being is further complicated by methodological inconsistencies across studies. Variations in sampling strategies, such as convenience or purposive sampling, risk introducing selection bias and limiting result generalizability [35]. Concurrently, insufficient control of circadian factors in HRV measurement may obscure true biological distinctions between groups [36]. To address these challenges, this study systematically examines sex differences in mental well-being among college students by integrating HRV with standardized psychological assessments, while implementing stratified sampling to mitigate bias and standardizing measurement timing to account for circadian effects.

Method

Participants

This study recruited 240 college students (120 males and 120 females) through random cluster sampling. The sample size was estimated using G*Power 3.1.9.7 [37], with a test set to compare the difference between two independent means (two groups) two-tailed with an assumed effect size of 0.5. Setting the significance level (α) at 0.05

and the power (1-β) at 0.95, it was determined that each group required a sample size of 105 participants. The inclusion criteria were as follows: (1) age between 18 and 22 years; (2) no current musculoskeletal or joint injuries; (3) no cardiorespiratory disorders; (4) no mental disorders. To control for confounding factors, students were requested to (1) avoid prolonged, high-intensity exercise 48 h before testing; (2) abstain from consuming caffeinated drinks 2 h before testing; (3) for female participants, schedule the test between the third and tenth days following the end of menstruation [38]; (4) conduct testing between 8 AM and 12 PM; (5) watch two videos during testing to divert attention from heart rate and breathing pattern measurements. The video content was about introducing plants, and it was rated as neutral by three experts in the field of psychology (including one professor and two associate professors).

Sampling method

Cluster sampling was utilized. Physical education is a mandatory course for students at Zhejiang University, where they can choose their preferred sports. The available activities can be broadly categorized into six groups: (1) football, basketball, rugby; (2) badminton, table tennis, tennis, volleyball; (3) Taekwondo, boxing, and Sanda; (4) gymnastics, martial arts, boxing, sports dancing; (5) dragon boat dance, dragon lion dance, kayaking; and (6) Tai Chi and swimming. There were 474 physical education classes, each comprising approximately 30 students. Eighteen classes were selected using the computer random number method from a total of 474 classes, with three classes from each of the six sports categories. The three classes within each sports category were then randomly ordered. Students were enrolled class by class until 20 students of each sex had been selected from each category, resulting in a total sample size of 240 students. The experiment was conducted from September 1 to November 1, 2023.

Physiological and psychological measures

The study was conducted in accordance with the Declaration of Helsinki. It was evaluated and approved by the Ethics Committee of the Department of Psychology and Behavioral Sciences at Zhejiang University, under the approval number Zhejiang University Psychology Application [2023]039. The experiment was conducted in the teaching building, on Sundays, between 8:00 and 12:00. In the corridor, the participants received a paper copy of the informed consent form. If they still agreed to participate, they signed the form (the participants had received an electronic version of the informed consent form before arriving). Then they could sit on the chairs in the corridor.

After being called by their number, they entered the classroom. There were two classrooms, one for males and one for females. Both classrooms were equipped with air conditioning, with a temperature of 26 °C and humidity between 40% and 70%. The humidity was measured by a hygrometer produced by Deli Company (Hygrometer, no.9012). The participants first sat quietly for 5 min, and then an experimenter helped participants to wear the Polar H7 (Polar Company, Kempele, Finland) chest strap. The electrodes on the reverse side of the chest strap were moistened with water. The chest strap was placed below the pectoral muscles, while the sensor was placed on the xiphoid process of the sternum. Female experimenters assisted female students, while male experimenters for male students. Then, participants watched a video on an 11-inch Xiaomi Pad (resolution:2560 × 1600; Xiaomi, Beijing, China) that was placed 50–80 cm in front of them. The total recording of HRV in a resting state took 6 min. Afterward, the experimenter removed the chest strap, and participants entered the other classroom (there are also two in total, one for males and one for females), where participants filled out the Warwick-Edinburgh Mental Well-being Scale (WEMWBS) and the 21-item version of the Depression, Anxiety, and Stress Scale (DASS-21). At this point, the data collection was complete.

The HRV data were analyzed using Kubios software (Kubios HRV Standard 3.5.0). We set the beat correction as a low threshold. The rate of beat correction should not be more than 5%, otherwise, the participant's HRV data will not be used [39]. The total recording was 6 min, while the last five minutes were kept for analysis [40]. Regarding HRV variables, we selected three time-domain parameters and one frequency-domain parameter to comprehensively assess ANS activity. The time-domain measures included: Standard Deviation of Normal-to-Normal intervals (SDNN, unit: milliseconds), reflecting overall autonomic regulation; Root Mean Square of Successive Differences (RMSSD, unit: milliseconds), primarily capturing parasympathetic (vagal) modulation; and Percentage of successive NN intervals differing by > 50 ms (pNN50, unit: percentage), indicating short-term parasympathetic responsiveness. Additionally, we incorporated the frequency-domain parameter High-Frequency power (HF, unit: ms^2; 0.15–0.40 Hz), specifically to quantify respiratory-mediated parasympathetic activity [41].

The Chinese version of WEMWBS, a 14-item unidimensional tool, has been validated in a previous study of Chinese university students (Cronbach's α = 0.930) [42]. It assesses positive mental health using positively - worded statements, like "I've felt optimistic about the future". It uses a 5 - point scoring system (1 = never; 5 = always), and total scores range from 14 to 70. Higher scores indicated better positive mental health. The scale has been shown to be valid and reliable among male and female Chinese students [43].

The DASS-21, developed by Lovibond, was used to assess students' mental well-being [44]. The full scale, which contains 21 items with three subscales for depression, anxiety, and stress (each subscale consisting of seven items), had reliability alpha coefficients of 0.82, 0.82, and 0.79 for the depression, anxiety, and stress subscales respectively [44]. Scores are assigned on a four-point scale ranging from "0" (does not apply) to "3" (always applies) [44]. The score for each subscale is calculated by multiplying the subscale score by 2. Higher scores reflect increased severity of psychological distress across the measured dimensions [44]. This self-reported questionnaire distinguishes and defines depression, anxiety, and stress [44]. The depression scale is associated with low positive affect, the anxiety scale is related to physiological hyperarousability, and the stress scale is correlated with negative affect [45]. The Chinese version of DASS-21 has been validated for effectiveness and reliability [44]. Furthermore, it applies to both male and female students using the same standard score [46].

Statistical analysis

Statistical analyses were conducted using SPSS 27 (IBM, Armonk, New York, USA). First, we tested test the differences between males and females in psychological and physiological well-being. Skewness and kurtosis were used to assess univariate normality: skewness values ≥ |2| and kurtosis values ≥ |7| indicated a non-normal distribution [47]. The Levene's Test was applied for the test of homogeneity of variance. The outcome (HRV, WEMWBS, depression, anxiety, and stress) followed a normal distribution, and the data between males and females met the requirement of homogeneity of variance. Then Analysis of Covariance (ANCOVA) was employed for statistical analysis, with age, height, weight, and BMI as covariates. The effect sizes represented by partial eta-squared (η^2) ($0.01 \leq \eta^2 < 0.06$ indicating a small effect, $0.06 \leq \eta^2 < 0.14$ a moderate effect, and $\eta^2 \geq 0.14$ a large effect) [48]. In addition, the 95% confidence intervals for the effect sizes were presented.

Pearson's *r* correlation test was used to test the relationship between psychological and physiological indices. Since each questionnaire result (WEMWBS; DASS-21 Stress, Anxiety, and Depression scores) was compared with five measures of HRV individually, we adjusted the p-value and considered a correlation significant only when the p-value was less than 0.01, according to the Bonferroni method. The strength of the effect size (r) was adopted as negligible (Rho < 0.20), weak (0.21 < Rho < 0.40), moderate (0.41 < Rho < 0.60), strong (0.61 < Rho < 0.80), and very strong (0.81 < Rho < 1.00) [49].

Results

Description of subjects' basic characteristics

One female student's psychological questionnaire was missing, leaving 119 samples from female students and 120 samples from male students. The descriptive characteristics of the male and female groups are summarized in Table 1. Significant differences were observed in height and weight between the groups, but no statistically significant differences were found in age or Body Mass Index (BMI).

Results from HRV indices of male and female college students

The HRV signals collected from 3 male and 2 female students did not meet the set standard (with a correction rate of 5%). As a result, these signals were not used. Instead, data from the remaining 117 male and 117 female students were used for analysis.

We compared the HRV indices of male and female students. Covariates (age, height, weight, and BMI) were included in the ANCOVA analysis, and results indicated that they did not significantly affect the outcomes ($p > 0.05$, Partial $\eta^2 < 0.014$), except for height, which had a significant impact on the comparison of normalized HF power ($F = 5.150$, $p = 0.024$, Partial $\eta^2 = 0.022$). Therefore, height was included as a covariate in the analysis of normalized HF power. However, even without adjusting for height, there was no significant difference in normalized HF power between female and male students ($F = 0.888$, $p = 0.347$, Partial Eta² = 0.004). SDNN (ms), RMSSD (ms),

Table 1 Basic characteristics of subjects

	Male			Female			F	*p*
	n	**mean**	**SD**	***n***	**mean**	**SD**		
Age	120	19.83	0.83	119	19.9	0.8	0.398	0.529
Height(cm)	120	173.76	6.15	119	162.22	5.27	243.21	< 0.001**
Weight(kg)	120	64.67	8.92	119	54.79	6.87	92.448	< 0.001**
BMI(kg/m^2)	120	21.38	2.47	119	20.8	2.33	3.414	0.066

BMI Body Mass Index

** $p < 0.01$

Table 2 Results from HRV indices of male and female college students

	Male			Female			F	P	Partial η^2	95% CI	
	n	mean	SD	*n*	mean	SD				Lower	upper
SDNN(ms)	117	31.81	10.24	117	23.37	9.34	43.42	$<0.001^{**}$	0.158	0.081	0.242
RMSSD(ms)	117	22.46	11.85	117	16.95	9.22	15.76	$<0.001^{**}$	0.064	0.016	0.132
pNN50(%)	117	5.089	7.672	117	2.323	4.794	10.93	$<0.001^{**}$	0.045	0.007	0.107
absolute HF power (ms^2)	117	240	237	117	157	177	9.148	0.003^{**}	0.038	0.005	0.097
normalized HF power (n.u.)	117	25.2	16	117	27.0	13.6	0.894	0.345	0.004	0.000	0.035

SDNN Standard Deviation of Normal-to-Normal intervals,*RMSSD* Root Mean Square of Successive Difference,*pNN50* Percentage of successive NN intervals differing by more than 50 milliseconds, *HF* High-frequency

$^{**}p<0.01$

Table 3 Results from questionnaires of male and female college students

	Male			Female			F	p	Partial η^2	95% CI	
	n	mean	SD	*n*	mean	SD				Lower	upper
WEMWBS	120	51.51	7.50	119	49.66	6.79	3.969	0.047^{*}	0.016	0.000	0.062
DASS21-Stress	120	11.13	5.87	119	11.61	5.75	0.408	0.524	0.002	0.000	0.027
DASS21-Anxiety	120	7.9	4.69	119	9.26	5.11	4.597	0.033^{*}	0.019	0.000	0.066
DASS21-Depression	120	6.35	6.22	119	6.86	5.42	0.452	0.502	0.002	0.000	0.028

WEMWBS Warwick-Edinburgh Mental Well-being Scale, *DASS21* Depression Anxiety Stress Scale-21

$^{*}p<0.05$

Table 4 Results from correlations between students' psychological scale scores and HRV indices ($n=117$)

Groups	HRV indices	WEMWBS	Stress	Anxiety	Depression
		r	*r*	*r*	*r*
Male	SDNN (ms)	–0.029	0.020	–0.002	–0.031
	RMSSD (ms)	0.119	–0.033	–0.004	–0.084
	pNN50 (%)	0.053	–0.034	0.015	–0.076
	absolute HF power (ms^2)	0.008	0.084	0.129	–0.057
	normalized HF power (n.u.)	0.112	0.115	0.169	–0.070
Female	SDNN (ms)	0.034	–0.002	–0.155	0.026
	RMSSD (ms)	0.083	–0.042	– 0.245*	–0.065
	pNN50 (%)	0.032	0.089	– 0.205	0.074
	absolute HF power (ms^2)	0.065	–0.058	– 0.261*	–0.042
	normalized HF power (n.u.)	0.053	–0.135	– 0.262*	–0.163

HRV Heart rate variability, *WEMWBS* Warwick-Edinburgh Mental Well-being Scale *Stress, DASS21* Stress scores, *Anxiety, DASS21-Anxiety scores* Depression, *DASS21* Depression scores, *SDNN* Standard Deviation of Normal-to-Normal intervals, *RMSSD* Root Mean Square of Successive Differences, *pNN50* Percentage of successive NN intervals differing by more than 50 milliseconds, *HF* High-frequency

$^{*}p<0.01$, $^{**}p<0.001$ (no *p* value was less than 0.001)

pNN50 (%), and absolute HF power (ms^2) were analyzed without covariates.

As shown in Table 2, female students had significantly lower SDNN, RMSSD, pNN50, and absolute HF power compared to male students.

Results from questionnaires

As shown in Table 3, there were no statistically significant differences between male and female college students in depression scores and stress scores. However, female college students exhibited higher anxiety scores, which indicates that female students exhibited higher anxiety than male students ($p=0.033$, Partial $\eta^2=0.019$). Meanwhile, female students showed lower WEMWBS scores ($p=0.047$, Partial $\eta^2=0.016$), which means they had worse mental well-being.

Results from correlations between questionnaires and HRV indices

We further tested the correlation between psychological and physiological indicators in male and female college students. We found that only anxiety scores and HRV variables were significantly correlated in female students, as shown in Table 4. Specifically, RMSSD (r = –0.245, $p=0.008$), absolute HF power (r = –0.261, $p=0.005$), and normalized HF power (r = –0.262, $p=0.005$) were negatively correlated with anxiety scores, with a weak effect size.

Discussion

The purpose of this cross-sectional study was to investigate whether there are differences in the mental well-being of male and female college students using psychological scales and HRV and to explore how to better use these tools to assess the mental well-being of college students. We recruited 120 male and 120 female students using block randomization. All tests were conducted on weekend mornings to minimize sampling bias and circadian effects. The results showed that HRV indices indicated lower parasympathetic activity in female students compared to male students. At the same time, female students have lower mental well-being, with anxiety being particularly prominent. Additionally, we observed a notable link between female students' anxiety and parasympathetic nervous system activity. The RMSSD and absolute HF components of HRV, which reflect parasympathetic function, seemed to be closely related to female students' anxiety. This suggests that more attention should be paid to anxiety issues among female college students. When assessing anxiety in female students, it is recommended to use psychological scales in conjunction with the RMSSD and absolute HF indices of HRV.

Malone et al. indicate that higher levels of anxiety are significantly associated with lower well-being [50], which aligns with our findings. Evidence-based studies further suggest that female university students in mainland China were more prone to anxiety between the years 2000 and 2015 [51]. A 2020 longitudinal study of Chinese undergraduate students also revealed that female students had higher average anxiety scores than their male counterparts, while no significant sex differences were observed in depression or stress levels [11]. These findings are consistent with ours.

As for the results of HRV, we observed that the female students had significantly lower HRV than male students across multiple indices, including RMSSD, SDNN, pNN50%, and absolute HF. Our findings are consistent with a finding of a meta-analysis on SDNN, but inconsistent with its results on RMSSD, and even contrary to its result on absolute HF [30]. One possible explanation for this discrepancy is the age range between our participants (18–22 years) and those from that meta-analysis (18–73 years), as HRV is significantly influenced by aging [30]. In addition, this meta-analysis did not consider mental state (e.g., stress and anxiety), although mental state substantially affects HRV [30]. Another recent study examined sex differences in HRV (using a heart rate monitor) and mental well-being (using questionnaires) [52]. Interestingly, the researchers found that female participants had significantly higher anxiety scores than male participants [52]. However, RMSSD was significantly higher in the female teachers compared to the male teachers. Additionally, normalized HF was also significantly higher in females. The author suggested that females with higher stress, higher anxiety, and higher RMSSD (greater parasympathetic activity) demonstrated greater physiological resilience to stress [52]. Research has consistently shown that females with lower HRV are more susceptible to emotional disturbances such as anxiety and depression during periods of sustained stress and are also at a heightened risk for cardiovascular disease [53, 54]. As we found that female students exhibited worse mental well-being and higher anxiety than male students, as well as lower HRV (RMSSD, SDNN, absolute HF), these findings may indicate that younger female students not only experience a worse mental state but also have poorer physiological resilience to distress.

One important aim of our research was to explore how to use psychological scales and HRV better to reveal the mental health status of college students. Therefore, we tested the correlations between the indices of psychological scales and HRV. We found a negative correlation between the levels of anxiety and both RMSSD and HF in female students, suggesting that higher anxiety is associated with lower parasympathetic nervous system activity. Our findings support the idea that HRV may be a useful biomarker for anxiety [55]. This is consistent with a study by Nas et al., which also found a negative correlation between HF and anxiety [56]. However, studies by Ham et al. and Tomasi et al. found no significant correlation between self-assessment anxiety and various measures of HRV [57, 58]. These discrepancies may arise from differences in sample characteristics. The sample used by Ham et al. consisted of anxiety patients from psychiatric clinics with a broad age range.

Regarding the link between anxiety and HRV in female students, a *neurovisceral integration model may provide a useful framework for understanding. One* study *showed that females exhibit stronger activation of the amygdala and thalamus during the processing of negative emotions* [59]. This heightened subcortical response may impair the prefrontal cortex (PFC)'s ability to regulate the ANS, leading to reduced parasympathetic activity (e.g., lower HF and RMSSD) [60, 61]. In contrast, males tend to rapidly suppress threat signals through efficient PFC-amygdala connectivity [62], whereas females rely more on resting-state functional connectivity between the thalamus and amygdala [63]. These differences in neural connectivity patterns may make it more challenging for females to effectively modulate their ANS in response to anxiety. Despite controlling for the menstrual cycle among female participants, variations in hormone levels, especially estrogen, may also exert an influence on these neural pathways [64]. These mechanisms offer a basis for using HRV as an anxiety biomarker and show the important role of sex in how anxiety affects ANS activity.

This study has certain limitations. First, the data was collected entirely from a single university, which may limit the generalizability of the findings to students from other institutions. Second, as this is a cross-sectional study, we were unable to observe changes in measures of HRV after students' anxiety symptoms improved. We recommend that future studies explore which measures of HRV most sensitively reflect the alleviation of anxiety symptoms in university students, as such findings could contribute to more effective monitoring of students' mental health. Third, we did not collect data on factors such as ethnicity, academic pressure, economic background, or regional cultural differences, which may influence HRV and anxiety. We acknowledge this limitation and suggest that future research incorporate these variables for a more comprehensive analysis.

Conclusion

Female university students exhibited significantly higher levels of anxiety and lower overall mental well-being compared to male students, as measured by the questionnaires. Additionally, the HRV indices indicated lower parasympathetic activity in female university students, suggesting poorer physiological resilience to distress. Based on our and others' findings, female university students (aged 18–21) may differ in physiological resilience to distress from older females (e.g., around 40), as noted in the discussion section. These findings urge educational authorities to pay special attention to the mental health issues of female college students.

Female university students' anxiety scores, as measured by a questionnaire, were significantly associated with HRV indices (RMSSD and absolute HF), integrating psychological scales with these HRV indices may enhance anxiety assessment in this population.

Abbreviations

HRV	Heart rate variability
WEMWBS	Warwick-edinburgh mental well-being scale
DASS-21	the 21-item version of the depression, anxiety, and stress scale
ANS	Autonomic nervous system
HF	High-frequency
SDNN	Standard deviation of normal-to-normal intervals
RMSSD	Root mean square of successive differences
pNN50	Percentage of successive NN intervals differing by > 50 ms
ANCOVA	Analysis of covariance
η^2	Partial eta-squared
BMI	Body mass index
PFC	Prefrontal cortex

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Authors' contributions

OR, KJ, WL, IT, ZB, and IG contributed to the conceptualization and methodology. KJ, WL, and YD contributed to data collection and/or processing. WL and IT contributed to the formal analysis. YZ and WL wrote the original draft; OR, YZ, WL, KJ, IG, ZB, and IT reviewed and edited the manuscript. All the authors have read and agreed to the published version of the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The study was evaluated and approved by the Ethics Committee of the Department of Psychology and Behavioral Sciences at Zhejiang University, under the approval number Zhejiang University Psychology Application [2023]039. Furthermore, all participants provided informed consent before they participated in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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