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Research Paper

Heart rate variability and pulse rate variability agreement in stress regulation: implications for political psychology

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ABSTRACT

Background: Heart rate variability (HRV) provides information about autonomic regulation and has been associated with resilience to stress. However, its assessment using electrocardiography (ECG) can present practical challenges for large studies and recordings outside the laboratory. Pulse rate variability (PRV), derived from photoplethysmography (PPG), and may provide a more accessible alternative.
Objective: This study evaluated agreement between ECG-derived HRV and PPG-derived PRV and examined age, body mass index (BMI), and cardiorespiratory fitness as determinants of HRV.
Methods: Simultaneous ECG and finger PPG recordings were obtained from 35 healthy adults (20 females and 15 males; mean age 23.1 years; mean BMI 27.5 kg/m^2) under standardised resting conditions. Agreement for the standard deviation of normal-to-normal intervals (SDNN) was evaluated using correlation and Bland-Altman analysis. Multiple linear regression assessed age, BMI, and peak oxygen consumption (VO_2peak) as predictors of ECG-derived SDNN.
Results: PRV correlated strongly with HRV for SDNN ($r = 0.94$, $p < 0.001$). The mean ECG-minus-PPG bias was 3.30 ms, with 95% limits of agreement from -9.48 to 16.08 ms. Age was negatively associated with SDNN (B = -2.14 ms/year, $p < 0.001$), whereas VO_2peak was positively associated (B = 1.76 ms per ml/kg/min, $p = 0.005$). BMI was not independently associated after adjustment. The regression model explained 52% of SDNN variance.
Conclusion: Resting PRV provides an accessible approximation of HRV for group-level research in healthy young adults. Its use may facilitate wearable-based investigation of autonomic responses in psychological and political settings. Age and fitness should be measured and modelled when interpreting HRV or PRV, while individual-level interchangeability and broader population validity require further study.

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1. INTRODUCTION

Heart rate variability (HRV) describes beat-to-beat variation in cardiac intervals and provides a non-invasive window on autonomic regulation. HRV can be described using time-domain and frequency-domain measures. Time-domain indices include the standard deviation of normal-to-normal intervals (SDNN), while frequency-domain analysis describes how variability is distributed across specified frequency bands [1]. These measures describe variation between successive heartbeats rather than average heart rate. Their values depend on autonomic influences, breathing, posture, physical activity and recording duration. Interpretation therefore requires consistent recording conditions and clearly documented signal processing. An association between HRV and another variable does not, by itself, establish a causal relationship.

HRV also has relevance to psychological research. A meta-analysis of HRV and neuroimaging studies supported the neurovisceral integration model, which links cardiac autonomic regulation with brain networks involved in attention, inhibition and emotion [2]. Clinical and behavioural studies have associated higher resting HRV with emotional regulation and resilience, while reduced HRV has been reported in several affective and stress-related conditions [3]. These findings support its use as a physiological measure alongside psychological assessments, although its meaning depends on the individual and the recording conditions.

ECG is the reference method for measuring HRV because its R peaks allow accurate identification of successive cardiac intervals. However, electrode placement, recording equipment and restrictions on movement can complicate repeated measurements outside the laboratory. PPG offers another approach by detecting changes in peripheral blood volume. Variability in the intervals between successive pulse waves is termed pulse rate variability (PRV). A systematic review reported close correspondence between PRV and HRV during stable rest, but found that this correspondence could change with movement, posture, illness and vascular conditions [4]. Short-term HRV measurements also differ in reliability according to the index and recording protocol used [5].

Wearable PPG sensors make repeated recordings possible during everyday activities. A daily-life validation study found that some PPG-derived measures approximated ECG-derived values when signal quality was adequate [6]. Nevertheless, pulse timing reflects both cardiac intervals and the time taken for the pulse wave to reach the measurement site. Vascular tone, temperature, sensor contact and processing algorithms can also affect PRV. A strong correlation with HRV is therefore insufficient to establish that the two methods can be used interchangeably. Method comparison must examine the size, direction and spread of their differences.

Participant characteristics provide another source of variation. Age-related reductions in HRV have been reported in people without known heart disease [7], while physical activity has been associated with more favourable HRV profiles [8]. BMI may also be associated with HRV, but it does not distinguish body composition from aerobic fitness. Because age, BMI and fitness may be related to one another, their associations with HRV should be examined together rather than interpreted solely from separate correlations.

These measurement questions are relevant to political psychology. Previous studies have reported associations between baseline cortisol and voting frequency [9], between brain connectivity and political attitudes [10], and between resting HRV, perceived chronic stress and ambiguity avoidance [11]. Physiological measures may therefore contribute to research on responses to political information when combined with self-report and behavioural observations. Portable PRV recording could support studies during media exposure, civic events or election periods. Such applications would first require validation under the relevant conditions and assessment of factors that could influence the recordings. The present study did not directly test political attitudes or responses to political events.

This study compared ECG-derived HRV with PPG-derived PRV using SDNN, with agreement assessed through Bland–Altman analysis. It also examined the adjusted associations of age, BMI and peak oxygen consumption (VO_2peak) with ECG-derived SDNN. A further aim was to discuss possible applications of PRV in political psychology within the limits of the measurements obtained. We hypothesised that HRV and PRV would be strongly correlated during rest, with a small mean difference, and that age and fitness would remain associated with HRV after adjustment.

2. RELATED WORK

2.1 HRV as a Marker of Autonomic Regulation

HRV indices describe different aspects of variation between heartbeats. SDNN summarises variability across the recording period, whereas RMSSD and pNN50 describe differences between consecutive normal-to-normal intervals. High-frequency power is influenced by breathing and vagal modulation. Low-frequency power has several physiological contributors, which limits the interpretation of the LF/HF ratio as a measure of sympathovagal balance. Researchers should select indices that suit their study question, report the recording duration and conditions, and keep physiological interpretations within the limits of each measure [12]. In interdisciplinary studies, these distinctions help prevent a single HRV value from being interpreted as a general measure of stress or resilience.

2.2 PRV as an Alternative to ECG-derived HRV

PPG detects the arrival of each peripheral pulse wave rather than the electrical initiation of the heartbeat. Under stationary resting conditions, the interval series can closely follow ECG R-R intervals. Laboratory comparison of finger-tip PPG with lead II ECG found high interval correlation and agreement across several variability indices [13]. Wearable ring PPG has likewise demonstrated feasible assessment of nocturnal heart rate and HRV relative to medical-grade ECG [14]. Nevertheless, peripheral vasoconstriction, altered vascular compliance, motion, irregular rhythms, and changing pulse transit time can separate PRV from HRV. Validation obtained in one device, body site, posture, or population should not automatically be transferred to another.

Method-comparison studies also require more than a statistically significant correlation. Two methods may correlate highly while one consistently overestimates the other. Mean bias estimates systematic difference, while limits of agreement describe the range in which most paired differences are expected. Whether that range is acceptable depends on the intended use. A difference tolerable for comparing group means may be unacceptable for clinical decisions or individual longitudinal feedback. The present study therefore frames PRV as a possible group-level research surrogate and does not claim clinical interchangeability.

2.3 Demographic and Fitness-related Determinants

Large age-span observations have shown progressive declines in time-domain HRV and changes in mean heart rate across adulthood [15]. Age can therefore confound any comparison between groups that differ demographically. Fitness is another relevant source of variation. In young overweight adults, physical activity and cardiorespiratory fitness correlate with HRV [16], supporting the inclusion of an objective fitness indicator rather than relying on BMI alone. BMI cannot distinguish fat from lean tissue or

directly describe aerobic capacity. Simultaneous modelling of age, BMI, and VO_2peak helps determine whether an apparent body-size association persists after these correlated influences are considered.

2.4 HRV in Psychological and Political Research

Reduced HRV is reported in depression, and treatment status, symptom severity, medication, and comorbidity may influence the observed association [17]. This clinical literature illustrates a broader principle for political psychophysiology: HRV is shaped by multiple interacting characteristics and should be interpreted alongside health, behaviour, and context. Experimental research has used HRV to study autonomic conflict during racially biased and socially regulated behaviour [18]. Together with work on cortisol, neural connectivity, and ambiguity avoidance [9], [10], [11], these studies show how physiological recording can complement explicit responses that may be affected by recall or social desirability.

The unresolved gap is practical as well as conceptual. Laboratory ECG provides strong temporal precision but can constrain movement and ecological validity. Wearable PPG enables repeated sampling but introduces peripheral and algorithmic influences. Few studies integrate method agreement with demographic and fitness covariates while discussing a clear interdisciplinary use case. The present analysis addresses that gap for healthy young adults at rest and defines conditions under which PRV may support, but not replace, rigorous psychophysiological measurement.

2.5 Measurement Validity and Interpretive Boundaries

Three forms of validity are relevant when transferring PRV into behavioural research. Technical validity concerns whether the sensor detects pulse peaks accurately. Method validity concerns whether intervals and derived indices agree sufficiently with ECG-derived values. Construct validity concerns whether the selected variability measure meaningfully represents the regulatory process named in the research question. Strong performance at one level does not guarantee performance at the next. For example, a device may detect pulses consistently while proprietary smoothing changes short-term variability, or PRV may agree with HRV at rest without capturing a rapid vascular response during threat exposure. Transparent reporting should therefore separate device performance, method agreement, and psychological interpretation.

Sampling design also affects validity. Between-person studies compare individuals and are sensitive to stable demographic and health differences. Within-person studies compare the same participant across time and may reduce some stable confounding, but they remain vulnerable to posture, respiration, activity, temperature, and circadian variation. Event-based studies require timestamps that align physiological data with stimulus onset and recovery periods. In every design, preregistered exclusion rules can reduce selective data removal after outcomes are known. These considerations inform the present emphasis on a controlled resting comparison before extension to more complex environments.

3. METHODOLOGY

3.1 Study Design and Participants

A cross-sectional study was conducted to compare the measurement methods and examine associations with participant characteristics. Recruitment through institutional announcements yielded 35 healthy adults aged 19–39 years, comprising 20 females and 15 males. Individuals were excluded if they had known cardiovascular disease, hypertension or diabetes mellitus, were current smokers, or used medication known to influence heart rate or autonomic function. Written informed consent was obtained from every participant before enrolment. The protocol received approval from the Institutional Ethics Committee of Lokmanya Tilak Municipal Medical College, Mumbai (LTMMC/IEC/2024/042). Study procedures followed the Declaration of Helsinki.

3.2 Anthropometry and Cardiorespiratory Fitness

Height was measured without footwear using a wall-mounted stadiometer, with readings recorded to the nearest 0.1 cm. A calibrated electronic scale was used to measure body mass to the nearest 0.1 kg. BMI was calculated by dividing body mass in kilograms by the square of height in metres. Bioelectrical impedance analysis provided estimates of body fat percentage and visceral fat rating.

Resting heart rate was recorded after 10 minutes of supine rest. Participants then completed incremental cycle ergometry to volitional exhaustion. After three minutes of unloaded pedalling, workload increased by 25 W each minute. Expired gases were analysed continuously using a calibrated metabolic system. VO_2peak was defined as the highest 30-second moving average oxygen uptake attained, and ECG monitoring continued throughout exercise.

3.3 HRV and PRV Signal Acquisition

Simultaneous resting ECG and PPG recordings were obtained between 08:00 and 10:00 at an ambient temperature of 22-24°C after a 10-minute supine stabilisation period. Participants refrained from caffeine and alcohol for 12 hours and vigorous physical activity for 24 hours before testing. These controls were used because time of day, recent exertion, stimulants, posture, and respiration can influence cardiac interval variability. ECG was acquired using a three-lead configuration sampled at 1000 Hz. Transmission-mode PPG was recorded simultaneously from the index finger. Standardised acquisition is consistent with evidence that HRV relates to autonomic and social-cognitive processing under controlled conditions [19].

3.4 Signal Processing and Outcomes

ECG R peaks and PPG pulse peaks were identified to construct successive interval series. Signals underwent corresponding preprocessing, and artefactual or non-physiological intervals were excluded before analysis. Time-domain measures were SDNN (ms), RMSSD (ms), and pNN50 (%). Frequency-domain measures derived by fast Fourier transformation were low-frequency power (LF, 0.04-0.15 Hz, ms^2), high-frequency power (HF, 0.15-0.40 Hz, ms^2), LF/HF ratio, and total power (ms^2), following established standards [1]. ECG-derived indices are denoted by subscript H and pulse-derived indices by subscript P. The primary method-agreement outcome was SDNN because it provided an interpretable time-domain measure of overall variability.

3.5 Statistical Analysis

Statistical analyses were performed using SPSS version 26.0. Variable distributions were assessed with the Shapiro–Wilk test. Variables with non-normal distributions were log-transformed before parametric analyses. Pearson correlation coefficients were calculated to assess associations between corresponding HRV and PRV indices. Agreement between the two SDNN measurements was evaluated using Bland–Altman analysis. For each participant, PPG-derived SDNN was subtracted from ECG-derived SDNN.

The mean paired difference represented the bias, and the 95% limits of agreement were calculated as this mean ± 1.96 times the standard deviation of the paired differences [20]. These estimates describe both the average difference between methods and the spread of differences across participants. Multiple linear regression was performed with ECG-derived SDNN (SDNN_H) as the dependent variable. Age, BMI and VO_2peak were entered together as predictors.

Unstandardised coefficients describe change in SDNN_H per unit of each predictor while holding the others constant. Because LF/HF has recognised interpretive limitations, it was treated descriptively and not used as the principal autonomic outcome [21]. An independent-samples t-test compared SDNN_H between BMI categories defined by the sample median (<27 and ≥27 kg/m^2), followed by analysis of covariance adjusting for age and VO_2peak. Statistical significance was set at two-tailed $p < 0.05$. Bland-Altman interpretation followed recommendations to consider the clinical or research purpose rather than relying on a universal numerical threshold [22].

Figure 1 summarises recruitment, standardisation, simultaneous signal acquisition, index derivation, and statistical analysis. The figure is a protocol schematic and contains no additional participant data.

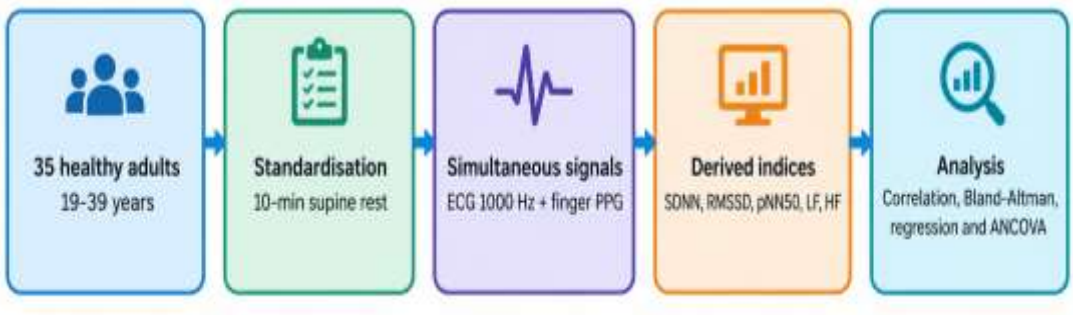


Figure 1. Study Design and Analytical Workflow

4. RESULTS AND DISCUSSION

4.1 Participant Characteristics

Participant characteristics are shown in Table 1. The sample was young, with a mean age of 23.1 years, and the mean BMI was 27.5 kg/m^2. Mean VO_2peak was 32.9 ml/kg/min. The relatively narrow age and BMI distributions should be considered when interpreting regression estimates and external validity.

Table 1. Participant Characteristics (N = 35)

Variable	Mean ± SD	Range
Age (years)	23.1 ± 5.3	19-39
Height (cm)	163.6 ± 7.1	155.5-174.0
Weight (kg)	73.7 ± 8.6	61.2-85.4
BMI (kg/m^2)	27.5 ± 1.8	25.1-29.9
Body fat (%)	31.5 ± 6.9	22.1-42.3
Visceral fat rating	7.8 ± 2.4	4-12
Resting heart rate (bpm)	72.3 ± 8.7	58-89
VO_2peak (ml/kg/min)	32.9 ± 6.2	23.5-44.8

4.2 HRV-PRV Association and Agreement

As shown in Table 2 corresponding HRV and PRV indices were strongly correlated. SDNN showed the highest reported correlation ($r = 0.94$, $p < 0.001$). RMSSD and pNN50 correlations were also above 0.90. Frequency-domain correlations remained high, although PRV values for HF and total power were greater than their ECG-derived counterparts. The systematic direction of these differences is consistent with the proposition that peripheral vascular timing contributes additional variability to the pulse interval series.

Table 2. ECG-Derived HRV and PPG-Derived PRV Indices (N = 35)

Variable	HRV (ECG)	PRV (PPG)	Correlation (r)
SDNN (ms)	57.8 ± 20.2	54.5 ± 19.6	0.94
RMSSD (ms)	46.7 ± 19.0	48.3 ± 18.9	0.92
pNN50 (%)	24.6 ± 17.5	26.3 ± 18.7	0.91
LF (ms^2)	800 ± 624	1091 ± 968	0.89
HF (ms^2)	657 ± 504	905 ± 798	0.90
LF/HF ratio	1.8 ± 1.2	1.7 ± 1.1	0.88
Total power (ms^2)	1901 ± 1305	2564 ± 1867	0.91

Bland-Altman analysis for SDNN yielded a mean ECG-minus-PPG bias of 3.30 ms and 95% limits of agreement from -9.48 to 16.08 ms. The positive bias indicates that ECG-derived SDNN was modestly higher on average. Strong correlation and modest mean bias support PRV for group-level research under similar resting conditions, but the limits show that an individual PRV value may differ meaningfully from the paired ECG value. Accordingly, the methods should not be described as universally interchangeable.

The intended use, expected effect size, and tolerance for individual error must determine acceptability [22]. The distinction between association and agreement is visible in these results. An r value of 0.94 indicates that participants with comparatively higher ECG-derived SDNN also tended to have higher PPG-derived SDNN. It does not establish equality of the two numerical measurements. The bias and limits of agreement provide the complementary information needed for substitution decisions. For an epidemiological comparison in which group differences are substantially larger than measurement disagreement, PRV may be adequate. For clinical classification near a threshold, or for feedback to a single participant, the observed range of paired differences could change interpretation. No diagnostic threshold was assessed in this study.

4.3 Predictors of ECG-derived SDNN

The regression model explained 52% of variance in SDNN_H (adjusted $R^2 = 0.47$; $F(3, 31) = 11.2$, $p < 0.001$). Table 3 shows that age and VO_2peak were independent predictors, whereas BMI was not. Each additional year of age was associated with a 2.14 ms lower SDNN_H after adjustment. Each 1 ml/kg/min higher known age-related decline in HRV [7], [15] and the favourable association between fitness and cardiac autonomic modulation [8], [16]. VO_2peak was associated with a 1.76 ms higher SDNN_H. These estimates are consistent with the

Table 3. Multiple Linear Regression Predicting Ecg-Derived SDNN

Predictor	B (SE)	Standardised β	p value
Intercept	45.21 (18.34)	-	0.020
Age (years)	-2.14 (0.48)	-0.56	<0.001
BMI (kg/m^2)	0.87 (1.12)	0.08	0.442
VO_2peak (ml/kg/min)	1.76 (0.58)	0.45	0.005

4.4 BMI Subgroup Analysis

Participants below the median BMI (<27 kg/m^2, n = 16) had a lower unadjusted mean SDNN_H than those at or above the median (52.36 ± 18.3 versus 62.34 ± 19.7 ms; $t(33) = -2.14$, $p = 0.04$). After adjustment for age and VO_2peak, the BMI-group difference was no longer significant ($F(1, 31) = 1.28$, $p = 0.28$). The reversal illustrates why an unadjusted group comparison should not be interpreted as evidence that higher BMI improves autonomic regulation. In this sample, the apparent association was explained by the distribution of age and fitness. BMI also does not measure fat distribution, lean mass, or metabolic health directly.

4.5 Implications for Stress and Political Psychology Research

The resting measurements suggest that PRV merits further evaluation for research involving repeated recordings or group comparisons. Wearable PPG could make frequent measurements more practical and support recruitment of larger samples. Potential applications include monitoring around elections, during exposure to political media, or at public debates and civic events. These uses would require validation because agreement at rest does not establish accuracy during movement or emotional arousal. Such designs could reduce sole reliance on retrospective self-report and allow researchers to model within-person change. Wearable biomedical devices increasingly combine PPG with other signals, creating opportunities for multimodal measurement [23].

Multimodal designs can strengthen inference when each measure has a defined role. Self-report can characterise perceived stress and appraisal, behavioural tasks can index attention or choice, contextual data can identify the timing and nature of exposure, and PRV can describe autonomic-

associated cardiac interval dynamics. Convergence among measures would be more informative than treating PRV as a direct readout of emotion or ideology. Divergence may also be meaningful, but only after technical artefact and timing differences have been excluded. Researchers should define primary outcomes in advance to avoid selecting whichever wearable metric happens to produce a significant association.

Accessibility does not remove the need for design controls. Researchers should predefine rest duration, posture, time of day, recording length, device and firmware, sampling or interpolation procedure, artefact criteria, and the HRV/PRV indices of interest. Movement and poor peripheral perfusion may selectively degrade PPG. Analyses should report usable-recording rates and sensitivity to data-quality thresholds. Where acute arousal is expected to change vascular tone, a validation subsample with simultaneous ECG can establish whether PRV retains acceptable agreement in that specific context. PRV findings should be interpreted as variation in pulse intervals associated with autonomic influences.

They do not directly measure political beliefs or establish the presence of a particular psychological state. Age and fitness require consideration when selecting participants and analysing results. For example, an HRV difference between political groups could partly reflect differences in their age distributions. Fitness could also influence baseline values or responses to stress. Depending on the study design, matching, stratification, covariate adjustment or multilevel analysis may help account for these differences. Relevant health conditions, medication use, caffeine and nicotine intake, sleep, breathing and habitual activity should also be recorded where feasible. In the present study, BMI was no longer statistically significant after adjustment, indicating that BMI alone did not adequately account for the participant characteristics associated with HRV.

Repeated wearable recordings also require an analysis that accounts for observations being grouped within participants. Recording windows from the same person should not be treated as independent measurements. Multilevel models can distinguish changes within individuals from differences between individuals while incorporating activity and other factors that vary over time.

Signal loss requires particular attention. Movement may disrupt PPG recordings during the events researchers most want to examine. If excluded recordings disproportionately represent periods of arousal or activity, analysing only usable windows could produce a distorted account of the response. Reports should therefore describe how much data were excluded and when exclusions occurred. Where possible, retained and excluded periods should be compared using available contextual information, and sensitivity analyses should assess whether the findings depend on the chosen signal-quality threshold.

Collecting physiological recordings during political activity raises questions about privacy and consent. When linked with location or event information, these recordings may disclose sensitive details about participants' health, affiliations or responses. Consent materials should explain the research purpose, whether recording can be paused, how long data will be retained, who can access them, and whether further use is permitted. They should also describe how identifying information will be removed or protected. Findings should be reported in aggregate, with care to avoid profiling individuals or stigmatising political and demographic groups. Participants' concerns about being monitored may themselves affect behaviour and physiological responses.

The strong correlation between ECG-derived and PPG-derived SDNN is consistent with previous resting comparisons [4], [13]. However, correlation alone does not establish agreement, which may vary with physiological conditions and signal processing. Short-term HRV also varies between recording days [5]. Repeated measurements may therefore provide a more reliable estimate when the aim is to study stable differences between individuals. Studies of responses to specific events instead require a defined baseline and consistent assessment of change within each participant. Research on cardiac vagal recovery after acute stress has used varied methods and assessment periods [24]. Wearable studies should consequently assess resting values, responses during exposure and subsequent recovery separately.

4.6 Limitations and Future Directions

Several limitations constrain interpretation. First, the sample of 35 participants provides limited precision for estimating limits of agreement and regression coefficients. Second, participants were

healthy young adults with a narrow age range and predominantly overweight BMI values; results cannot be generalised to older adults, normal-weight samples, clinical populations, or people with arrhythmias. Third, recordings were obtained under controlled resting conditions. Agreement may be poorer during movement, cold exposure, acute emotional arousal, or daily-life activity. Fourth, the analysis emphasised SDNN and did not report device-specific artefact rejection performance, respiration, skin tone, or peripheral perfusion, all of which may influence PPG validity. Fifth, psychological stress and political variables were not measured, so the political-psychology applications discussed here are prospective rather than directly tested.

Future research should recruit larger and more diverse samples, prespecify clinically or scientifically acceptable agreement limits, and validate PRV under the exact conditions in which it will be used. Simultaneous ECG-PPG recording should be extended across posture, paced and spontaneous breathing, controlled stress tasks, and ambulatory movement. Device-level studies should report missingness and artefact burden across participant characteristics. Repeated-measures studies could assess whether PRV tracks changes during stress and recovery within individuals, even when its absolute values differ from those obtained using ECG. Comparisons with reference values also require care because short-term HRV varies considerably among healthy adults [24]. In political psychology, physiological recordings should be interpreted alongside validated self-report instruments, behavioural observations and information about the setting. Biological measurements alone cannot establish a person's political beliefs or explain their behaviour.

5. CONCLUSION

In this sample of healthy young adults, PPG-derived PRV was strongly correlated with ECG-derived HRV for SDNN measured at rest. The mean difference between methods was small, although the limits of agreement showed variation in individual measurements. These findings support further evaluation of PRV for group comparisons and repeated recordings under controlled conditions. They do not establish that PRV and HRV can be used interchangeably for individual assessment.

Age and cardiorespiratory fitness independently predicted ECG-derived SDNN, whereas BMI did not remain significant after adjustment. These findings reinforce the need to measure and model demographic, fitness, health, and behavioural influences in psychophysiological research. Wearable PRV may expand naturalistic study of stress regulation in political and social contexts, but future work must validate each device and context, report artefact handling, and integrate physiological observations with psychological and behavioural evidence.

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Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Dr. Noorin Bhimani	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓
Sonia Poonawalla	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

Informed Consent

All participants provided written informed consent before enrolment. The consent process explained the study procedures, potential risks, confidentiality protections, voluntary participation, and the right to withdraw without penalty.

Ethical Approval

The study protocol was approved by the Institutional Ethics Committee of Lokmanya Tilak Municipal Medical College, Mumbai (approval no. LTMMC/IEC/2024/042). All procedures conformed to the Declaration of Helsinki.

Data Availability

The datasets generated and analysed during the study are available from the corresponding author upon reasonable request. Raw physiological data are not publicly archived because of participant confidentiality requirements; anonymised data and summary statistics may be provided where consistent with the consent and ethics approval.

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