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RESEARCH ARTICLE

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EFFECTS OF SUBMAXIMAL TEST ON HEART RATE RECOVERY IN HYPERTENSIVE PATIENTS

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ABSTRACT

Background: Hypertension is associated with impaired regulation of the autonomic nervous system, resulting in altered cardiovascular responses during and after physical activity. Heart rate recovery (HRR) following exercise is a simple, non-invasive, and reliable indicator of autonomic function and cardiovascular health. Delayed HRR is associated with increased cardiovascular morbidity and mortality in hypertensive individuals. Post-exercise recovery position may influence venous return, autonomic reactivation, and the speed of heart rate normalization; however, limited evidence exists regarding the most effective recovery posture following submaximal exercise in hypertensive patients. **Aim:** This study sought to determine the most effective recovery position for optimizing cardiovascular recovery in hypertensive individuals, supporting improved hypertension management strategies. **Methodology:** A cross-sectional study was conducted on 36 hypertensive patients aged 30–60 years. Participants performed the Queen College Step Test, and heart rate was measured immediately post-exercise and during recovery at 1, 5, and 10 minutes across three recovery positions—supine, trunk-forward leaning, and standing—assigned in a randomized, counterbalanced manner. Repeated-measures ANOVA (jamovi) compared heart rate recovery across positions and time intervals. **Result:** A significant effect of time on heart rate was found ($p < 0.001$), but no significant between-group effect ($p = 0.647$). A significant time × group interaction ($p = 0.015$) indicated differing recovery patterns across groups. Heart rate reductions from immediate post-exercise to 1 and 5 minutes were significant ($p < 0.001$), with near-complete recovery by 10 minutes. Trunk-forward leaning showed comparatively faster recovery. **Conclusion:** Body position during recovery influences HRR pattern and rate in hypertensive patients. Heart rate remained elevated at 1 and 5 minutes across groups, indicating delayed autonomic recovery. Trunk-forward leaning showed the fastest early decline, supine approached near-complete recovery by 10 minutes, and standing was slowest, suggesting recovery posture affects cardiovascular recovery post-exercise.

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INTRODUCTION

Hypertension remains one of the most significant global public health challenges, affecting approximately 1.4 billion adults aged 30–79 years worldwide and contributing to an estimated 7.1 million deaths annually (1,2). Epidemiological evidence demonstrates a log-linear increase in cardiovascular risk associated with blood pressure elevation beyond 115/75 mmHg (3), with fewer than one in five hypertensive adults achieving adequate control (1). In India specifically, hypertension prevalence among adults has been reported at 30.7%, with significant gaps in awareness and treatment (4,5). The pathogenesis of hypertension involves a complex interplay of genetic predisposition, neurohormonal dysregulation, vascular dysfunction, and environmental factors, with disruption of normal blood pressure homeostasis mediated through the autonomic nervous system (ANS), renin-angiotensin-aldosterone system, and renal sodium handling (3,6). Autonomic dysregulation, characterized by enhanced sympathetic activity and attenuated parasympathetic modulation, is a hallmark feature of the hypertensive state and contributes to elevated heart rate, increased cardiac contractility, and peripheral vasoconstriction (6,7,8) this imbalance not only drives disease progression but also predisposes patients to end-organ damage and adverse cardiovascular outcomes (7,9). Heart rate, as a readily accessible and non-invasive biomarker, reflects the integrity of autonomic regulation, and heart rate recovery (HRR) following exercise—governed initially by vagal reactivation and subsequently by sympathetic withdrawal—serves as a reliable indicator of cardiovascular health [10,11,12], with delayed HRR independently associated with increased cardiovascular mortality risk [13]. Submaximal exercise protocols such as the Queen's College Step Test offer a practical, low-cost alternative to maximal testing for evaluating cardiorespiratory fitness in clinical populations, including hypertensive patients [14,15]. Since post-exercise recovery involves changes in venous return, gravitational load, and respiratory mechanics, body position during recovery may significantly influence the rate of heart rate normalization[16,17,18]; despite this, current hypertension management guidelines do not specify an optimal recovery posture following exercise [19,20]. This study therefore investigates the effect of supine, trunk-forward leaning, and standing recovery positions on heart rate recovery in hypertensive patients following submaximal exercise.

METHODOLOGY

Study Design: A cross-sectional study design was employed, in which all measurements were obtained from participants during a single phase of data collection, with recovery positions assessed across separate testing days.

Study Population and Sampling: The study population comprised hypertensive patients with controlled blood pressure readings of 140/90 ± 10 mmHg while on antihypertensive medication. A convenience sampling method was used to recruit eligible patients from clinical settings, and simple random allocation using the lottery method was applied to determine the order in which recovery positions were assigned to each participant.

Sample Size: A total of 36 hypertensive patients aged 30–60 years were recruited. The sample size was determined using G*Power analysis with an effect size of 0.25, a Type I error (α) of 0.05, and statistical power ($1 - \beta$) of 0.80 for a three-group repeated-measures design, yielding a required sample size of 36 participants.

Study Duration and Setting: The study was conducted over a period of one year. Participants were recruited from hospitals and physician clinics, where all assessments and step-test procedures were performed.

Eligibility Criteria: Inclusion criteria: confirmed medical diagnosis of hypertension; successful completion of the Physical Activity Readiness Questionnaire (PAR-Q) indicating readiness for exercise participation; ability to safely perform the Queen's College Step Test; and both male and female participants aged 30–60 years. Exclusion criteria: presence of cardiovascular or respiratory disorders contraindicating physical exercise; recent surgical procedures that could interfere with physical activity or recovery; and any major medical condition compromising safety during exercise testing or influencing study outcomes.

Exercise Protocol: The Queen's College Step Test (QCST) was selected as the primary submaximal exercise protocol for assessing cardiovascular response and heart rate recovery, owing to its cost-effectiveness, safety, and minimal equipment requirements. Instruments used included a pulse oximeter, blood pressure monitor, stopwatch, a standardized step bench (16.25 inches in height), and a metronome to maintain stepping cadence. Standardized data sheets were used to record participant demographics, PAR-Q responses, heart rate values, and assigned recovery positions, and a first aid kit was available on-site throughout testing.

Procedure: Ethical approval was obtained from the Institutional Ethics Committee (IEC) of Sarvajanik College of Physiotherapy, Surat (ref. no. SMT/SCOP/ICE/24-25/690, dated 16/12/2024). Participants were first screened using the PAR-Q to confirm eligibility. Following informed consent, resting heart rate and blood pressure were recorded in a seated position to verify participants were within safe limits, after which the QCST protocol was explained, including stepping cadence, duration, and safety precautions. Each participant then performed the QCST, stepping up and down on the platform at a cadence of 22 steps per minute for 3 minutes, with a metronome maintaining rhythm. Heart rate was monitored continuously throughout the test to ensure safety and establish immediate post-exercise values.

Recovery Protocol and Positions: Immediately after completing the step test, each participant was guided into one of three assigned recovery positions: supine, trunk-forward leaning, or standing vertical. A randomized, counterbalanced schedule ensured that every participant performed recovery in all three positions on separate testing days, thereby minimizing order effects.

- **Supine Position:** Participants lay flat on their backs on a mat with arms relaxed at their sides and legs extended.

Figure 1. Supine recovery position

- **Trunk-Forward Leaning Position:** Participants sat at the edge of a chair or bench, leaning forward with elbows resting on the thighs and both feet flat on the ground.

Figure 2. Trunk-forward leaning recovery position

- Standing Vertical Position: Participants stood upright with feet shoulder-width apart and arms resting comfortably at their sides.

Figure 3. Standing vertical recovery position

Heart Rate Recovery Measurement: Heart rate recovery (HRR) was recorded at defined intervals during the recovery phase using a validated heart rate monitor to ensure accurate and consistent readings. Heart rate was measured immediately post-submaximal test (baseline recovery) and at 1 minute, 5 minutes, and 10 minutes during recovery.

Statistical Analysis: Heart rate recovery values across the three recovery positions were analyzed using repeated-measures ANOVA (jamovi) to determine significant differences across positions and time intervals. Where significant main or interaction effects were identified, Tukey-adjusted post hoc analyses were performed to determine specific pairwise differences between recovery positions and time points.

RESULTS

A total of 36 hypertensive patients (20 males, 16 females) completed the study, with 12 participants equally allocated to each recovery-position group: Group A (supine), Group B (trunk-forward leaning), and Group C (standing vertical). No missing data were recorded in any group. Gender distribution was comparable across groups, with Groups A and B each comprising 5 females and 7 males, and Group C comprising 6 females and 6 males, indicating no marked gender imbalance between groups. The mean age of participants was 49.2 ± 8.60 years in Group A, 56.1 ± 4.23 years in Group B, and 48.9 ± 10.46 years in Group C. The Shapiro–Wilk test indicated that age was normally distributed only in Group A ($p = 0.148$), while Groups B and C showed significant deviations from normality ($p = 0.005$ and $p = 0.006$, respectively). Resting heart rate was similar across groups, averaging 81.8 ± 13.64 bpm in Group A, 80.4 ± 8.96 bpm in Group B, and 79.3 ± 11.12 bpm in Group C. Heart rate rose sharply immediately after the step test in all groups and declined progressively over the 1, 5, and 10-minute recovery intervals. Most heart rate variables were normally distributed, although minor deviations were noted for resting heart rate in Group C, heart rate at 5 minutes in Group C, and heart rate at 10 minutes in Group B. There was a highly significant effect of time on heart rate ($F = 87.86$, $p < 0.001$, $\eta^2p = 0.727$), confirming that heart rate changed substantially from rest through recovery. A significant Time × Group interaction was also observed ($p = 0.015$), indicating that the pattern of heart rate recovery differed depending on recovery position; this interaction remained significant after Greenhouse–Geisser and Huynh–Feldt corrections for sphericity violation. Despite this interaction, the between-subjects analysis showed no overall difference in heart rate among the three positions ($F(2,33) = 0.441$, $p = 0.647$, $\eta^2p = 0.026$), meaning that when heart rate values were averaged across all time points, the groups did not differ significantly — the effect of position was on the *trajectory* of recovery rather than the overall heart rate level. Heart rate remained significantly elevated above resting values at 1 minute and 5 minutes ($p < 0.001$), while no significant difference was found between rest and 10 minutes ($p = 0.998$), indicating near-complete recovery by this time point. The decline between successive intervals was significant at every step, confirming a steady, progressive fall in heart rate throughout recovery. No significant differences in overall heart rate were found between any pair of groups (all $p > 0.05$), confirming that averaged across all time points, the three recovery positions produced statistically similar heart rate levels. Within each group, heart rate remained significantly elevated above resting values immediately after exercise and at 1 and 5 minutes (all $p < 0.05$). By 10 minutes, however, no group differed significantly from its own resting value (all $p > 0.05$), with Group B showing the smallest residual difference (4.00 bpm below rest), Group A showing near-complete recovery (1.58 bpm below rest), and Group C still trending 6.75 bpm above rest — the largest residual elevation of the three groups, suggesting comparatively slower recovery in the standing position.

DISCUSSION

This study demonstrates that recovery posture significantly influences the trajectory of heart rate recovery (HRR) following submaximal exercise in hypertensive patients, as reflected by the significant Time × Group interaction ($p = 0.015$). Heart rate remained markedly elevated above resting values at 1 and 5 minutes across all three positions, confirming that hypertensive patients exhibit delayed autonomic recovery consistent with the well-documented blunting of first-phase vagal reactivation in this population [(21,22)]. This early impairment reflects chronically reduced parasympathetic tone and sympathetic overdrive characteristic of hypertensive autonomic dysfunction [(23,24)], and is consistent with earlier reports that heart rate variability and autonomic balance are measurably reduced in individuals with elevated blood pressure [(25)]. Among the three positions, trunk-forward leaning produced the fastest decline in heart rate during the critical 1–5-minute window, likely reflecting the additive respiratory-mechanical benefits of this posture, which reduce inspiratory work and ventilatory demand, thereby lowering sympathetic cardiovascular load [(26,27)]. Supporting evidence from Hwangbo *et al.* similarly found trunk-forward leaning associated with reduced minute ventilation during recovery [(28)], while Kutac *et al.* reported comparable short-term cardiopulmonary advantages of this posture in athletic populations recovering from submaximal exercise [(29)].

The supine position, by contrast, approached near-complete recovery by 10 minutes primarily through enhanced venous return and cardiac preload via the Frank–Starling mechanism, consistent with earlier findings by Takahashi *et al.* and Buchheit *et al.* demonstrating superior parasympathetic reactivation in supine recovery [30,31]. The standing position showed the slowest recovery, likely due to sustained sympathetic activation required to counteract gravitational venous pooling, in agreement with Trybulski *et al.* and van der Stam *et al.*, who reported prolonged sympathetic dominance during upright positioning [32,33]. The prognostic implications of these recovery patterns are substantial. Cole *et al.* demonstrated that a first-minute HRR of less than 12 bpm is independently associated with increased all-cause mortality, a threshold not reached by any group in the present cohort during the first minute of recovery[34]. Jouven *et al.* similarly reported that a blunted exercise heart-rate profile independently predicts sudden cardiac death [35], while Imai *et al.* showed that the rate of heart rate decline in the early recovery phase—rather than the absolute value at any single time point—is the strongest predictor of cardiovascular outcomes [36]. These findings support the present study's emphasis on inter-interval recovery rate as a more clinically meaningful measure than isolated post-exercise heart rate values, and suggest that the modest first-minute recovery observed across all groups reflects a population-level autonomic vulnerability rather than a benign transitional response. Clinically, these findings support trunk-forward leaning as a practical, equipment-free recovery posture for hypertensive patients, while also underscoring the need for continued cardiovascular monitoring throughout the full 10-minute recovery period, given that adverse events are more common during this phase than during exercise itself [37]. The supine position, although effective for heart rate normalization, warrants caution given its established association with supine hypertension and elevated risks of heart failure, stroke, and all-cause mortality [38,39]. Overall, these results align with prior literature indicating that post-exercise posture meaningfully modulates autonomic recovery in hypertensive populations [40,41].

From a broader public health perspective, these findings are particularly relevant given the high burden of hypertension in India, where prevalence among adults has been reported at approximately 30–35%, alongside persistently poor rates of awareness, treatment, and control [42,43]. Since current major guidelines, including the 2023 ESH and 2024 ESC recommendations, endorse exercise as central to hypertension management but do not specify an optimal post-exercise recovery posture [44,45], the identification of trunk-forward leaning as a simple, low-cost, and immediately implementable strategy addresses a meaningful gap in existing clinical practice, particularly in resource-limited settings where equipment-based interventions may be impractical. Finally, heart rate remains a valuable but incomplete marker of autonomic status, and its established relationship with hypertension pathogenesis and cardiovascular risk further reinforces the clinical importance of these findings [46]. Future studies incorporating heart rate variability analysis alongside continuous blood pressure monitoring during recovery would provide deeper mechanistic insight into the differential autonomic pathways—respiratory-mechanical versus haemodynamic—through which recovery posture influences cardiovascular recovery in hypertensive individuals [25,47], and would help establish more definitive, posture-specific recommendations for clinical and rehabilitation practice.

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