Section: Physiology

Original Research Article

FUNCTIONAL EVALUATION OF AUTONOMIC BALANCE IN RURAL MANUAL WORKERS AT TERTIARY CARE HOSPITAL: A NON-INVASIVE PHYSIOLOGICAL STUDY

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Received *: 05/08/2025*
Received in revised form *: 21/09/2025*
Accepted *: 08/10/2025*

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DOI: 10.70034/ijmedph.2025.4.223

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2025; 15 (4); 1241-1245

ABSTRACT

Background: The autonomic nervous system (ANS) plays a vital role in regulating cardiovascular and respiratory homeostasis. Chronic physical labor may induce adaptive or dysregulated autonomic responses due to sustained sympathetic stimulation and postural stress. Despite the physical demands of rural occupations, limited data exist on the functional status of the ANS in this demographic. This study aimed to evaluate autonomic balance among rural manual laborers using non-invasive physiological tests in a small-town medical setting.

Materials and Methods: This cross-sectional observational study was conducted at Tertiary care hospital, with 60 apparently healthy male rural manual laborers aged 20–50 years. Participants with known systemic illnesses or on medications affecting ANS function were excluded. After recording baseline anthropometric and cardiovascular parameters, three autonomic function tests were conducted: (1) Deep Breathing Test to assess parasympathetic activity, (2) 30:15 Ratio (Active Standing Test) for baroreflex function, and (3) Cold Pressor Test to assess sympathetic reactivity. Data were analyzed using descriptive statistics and Pearson correlation between years of labor and autonomic parameters.

Results: The mean heart rate difference in the deep breathing test was 16.81 ± 5.48 bpm; 60% showed normal parasympathetic response. The mean 30:15 ratio was 1.11 ± 0.08 with 85% classified as normal. The cold pressor test revealed a mean SBP rise of 12.22 ± 3.89 mmHg; 68.3% had normal sympathetic reactivity. A weak positive correlation was found between years of manual labor and both 30:15 ratio (r = 0.231) and cold pressor test (r = 0.250), though not statistically significant.

Conclusion: Most rural laborers demonstrated preserved autonomic function, especially in sympathetic and baroreflex domains, with subtle trends indicating physiologic adaptation with longer labor exposure.

Keywords: Autonomic function, Manual labor, Cold pressor test, Baroreflex, Rural physiology.

INTRODUCTION

The autonomic nervous system (ANS) is a critical component of the human nervous system responsible for regulating involuntary physiological functions, including heart rate, blood pressure, respiration, digestion, and thermoregulation. It maintains homeostasis through the coordinated activity of its two primary branches: the sympathetic and parasympathetic systems, which generally exert opposing effects on target organs.[1] The sympathetic nervous system (SNS) prepares the body for stress-related activities ("fight or flight"), while the parasympathetic nervous system (PNS) promotes restorative functions ("rest and digest").[2]

Dysfunction of the ANS can lead to a wide range of clinical symptoms, from postural hypotension and fatigue to life-threatening arrhythmias.[3] Autonomic

testing — particularly heart rate variability (HRV), deep breathing tests, and cold pressor responses — is a valuable non-invasive approach for assessing the functional integrity of these pathways.[4] The physiological response to stress and activity, especially in populations engaged in chronic physical labor, can reflect subtle imbalances between sympathetic and parasympathetic control mechanisms.

Chronic manual labor, as is common in rural occupations such as farming, construction, and industrial work, may influence autonomic tone due to sustained physical stress, postural strain, and lack of structured rest cycles.[5] Studies suggest that such occupations may lead to adaptive changes or early dysfunction in autonomic parameters, potentially affecting cardiovascular resilience, fatigue thresholds, and even sleep quality.[6] Yet, most literature in this area focuses on urban industrial workers or comparative occupational studies, with a lack of data on rural populations, particularly in low-resource medical college settings.[7]

There is a pressing need to generate context-specific physiological data to inform occupational health strategies in India's rural workforce. A small-town tertiary medical institute like Tertiary care hospital, provides a unique opportunity to bridge this gap using low-cost, non-invasive methods suitable for community-based screening and primary prevention. This study aims to assess autonomic function in rural manual laborers using physiological autonomic tests and to explore potential trends with years of labor exposure. Such data could provide valuable insights into early physiological shifts before the onset of overt clinical disease.

MATERIALS AND METHODS

This was a cross-sectional observational study conducted in the Department of Physiology at Tertiary care hospital, from January to June 2024. The objective was to assess autonomic nervous system function among rural manual laborers using non-invasive, clinically feasible physiological tests. A total of 60 healthy male manual workers, aged between 20 and 50 years, were recruited from local villages and construction/agriculture sites. The sample size was determined based on previous similar studies examining autonomic function in occupational cohorts, with a confidence level of 95% and power of 80% to detect moderate autonomic variation.[1]

Participants included in the study had been engaged in consistent manual labor (≥6 hours/day) for at least 1 year. Individuals with known cardiovascular, respiratory, neurological, metabolic, or psychiatric disorders, smokers, alcoholics, and those on medications influencing autonomic function (e.g., beta-blockers, antihypertensives) were excluded. All participants were examined in a fasting state between 9:00 and 11:00 AM in a quiet, temperature-controlled lab setting. After 10 minutes of supine rest, baseline vitals — heart rate (HR), systolic and diastolic blood pressure (SBP/DBP), and mean arterial pressure (MAP) — were recorded using a validated digital sphygmomanometer and single-lead ECG system.

Autonomic function was evaluated using the following tests:

- Deep Breathing Test – measured HR variability during 6 deep breaths/min over 1 minute; the difference between maximal and minimal HR was noted.
- 30:15 Ratio (Active Standing Test) – assessed baroreflex response by calculating the ratio of R-R intervals at the 30th and 15th beats after standing.
- Cold Pressor Test – tested sympathetic reactivity via the rise in SBP following 1-minute immersion of the hand in cold water (4–6°C).

All values were manually recorded and entered into Microsoft Excel and SPSS version 26.0 for statistical analysis. Descriptive statistics (mean ± SD, frequencies, percentages) were calculated. Pearson correlation was used to evaluate the relationship between years of manual labor and autonomic parameters. A p-value < 0.05 was considered statistically significant.

RESULTS

A total of 60 apparently healthy male manual laborers from rural areas around Tertiary care hospital were included in the study. The demographic distribution of the participants is detailed in Table 1. The age of participants ranged from 20 to 50 years, with the highest proportion belonging to the 40–49 years category (46.7%), followed by 30–39 years (28.3%), and 20–29 years (23.3%). Only one participant (1.7%) was over 50 years of age. Regarding body mass index (BMI), a majority of individuals (70.0%) were within the normal range (18.5–24.9 kg/m²), while 21.7% were categorized as overweight, 6.7% as underweight, and only one individual (1.7%) met the criteria for obesity.

Occupational parameters showed that 43.3% of participants had been engaged in manual labor for over 15 years, while 38.3% had 6–15 years of experience, and 18.3% were relatively newer workers with <5 years of engagement. In terms of daily physical workload, more than half of the study population (56.7%) reported working 7–8 hours per day, with 26.7% working 9–10 hours and 16.7% restricted to 6 hours per day. This profile establishes a cohort predominantly involved in long-term, sustained physical labor with moderate-to-high daily exertion.

[Table 2] presents resting cardiovascular parameters in categorized formats. Resting heart rate (RHR) was <70 bpm in 41.7% of individuals, 70–79 bpm in 38.3%, and ≥80 bpm in 20.0%. The systolic blood pressure (SBP) was 110–129 mmHg in the largest segment (46.7%), followed by elevated SBP (≥130

mmHg) in 33.3%, and lower SBP (<110 mmHg) in 20.0%. A similar trend was observed in diastolic blood pressure (DBP), where 70–79 mmHg was noted in 46.7%, <70 mmHg in 33.3%, and ≥80 mmHg in 20.0% of participants. The calculated mean arterial pressure (MAP) ranged widely; 48.3% had MAP in the 85–94 mmHg range, while 30.0% had <85 mmHg and 21.7% had elevated MAP ≥95 mmHg.

Table 1: Participant Characteristics by Category (n = 60)

Variable	Category	Frequency (n)	Percentage (%)
Age Group (years)	20–29	14	23.3%
	30–39	17	28.3%
	40–49	28	46.7%
	50+	1	1.7%
BMI Category	Underweight	4	6.7%
	Normal	42	70.0%
	Overweight	13	21.7%
	Obese	1	1.7%
Work Duration (hrs/day)	6 hrs	10	16.7%
	7–8 hrs	34	56.7%
	9–10 hrs	16	26.7%
Years in Manual Labor	<5 years	11	18.3%
	6–15 years	23	38.3%
	>15 years	26	43.3%

Table 2: Resting Cardiovascular Parameters by Category (n = 60)

Variable	Category	Frequency (n)	Percentage (%)
Resting Heart Rate (bpm)	<70 bpm	25	41.7%
	70–79 bpm	23	38.3%
	≥80 bpm	12	20.0%
Systolic BP (mmHg)	<110 mmHg	12	20.0%
	110–129 mmHg	28	46.7%
	≥130 mmHg	20	33.3%
Diastolic BP (mmHg)	<70 mmHg	20	33.3%
	70–79 mmHg	28	46.7%
	≥80 mmHg	12	20.0%
Mean Arterial Pressure (mmHg)	<85 mmHg	18	30.0%
	85–94 mmHg	29	48.3%
	≥95 mmHg	13	21.7%

[Table 3] outlines autonomic function test results. The deep breathing test, which evaluates parasympathetic modulation, showed a mean HR difference of 16.81 ± 5.48 bpm, with a wide range from 0.8 to 27.7 bpm. The 30:15 ratio, reflecting baroreceptor reflex integrity during postural change, had a mean value of 1.11 ± 0.08, ranging from 0.96 to 1.31. The cold pressor test, indicative of sympathetic vasomotor response, yielded a mean systolic rise of 12.22 ± 3.89 mmHg, with minimum and maximum values of 3.5 and 20.8 mmHg, respectively.

Table 3: Autonomic Function Test Results of Study Participants (n = 60)

Autonomic Test	Mean	SD	Min	Max
Deep Breathing Test (HR Difference, bpm)	16.81	5.48	0.80	27.70
30:15 Ratio (Active Standing Test)	1.11	0.08	0.96	1.31
Cold Pressor Test (SBP Rise, mmHg)	12.22	3.89	3.50	20.80

Interpretative classification of autonomic test outcomes is presented in [Table 4]. For the deep breathing test, 36 participants (60.0%) demonstrated normal parasympathetic function (HR difference ≥15 bpm), 18 participants (30.0%) showed borderline response (10–14 bpm), and 6 participants (10.0%) had abnormal parasympathetic response (<10 bpm). In the 30:15 ratio test, 51 participants (85.0%) had normal baroreflex response (ratio ≥1.03), 6 (10.0%) were borderline (1.00–1.02), and 3 (5.0%) were classified as abnormal (ratio <1.00). For the cold pressor test, a normal sympathetic response (SBP rise ≥10 mmHg) was seen in 41 individuals (68.3%), 15 participants (25.0%) had borderline increase (6–9 mmHg), and 4 individuals (6.7%) had an abnormal response (<6 mmHg).

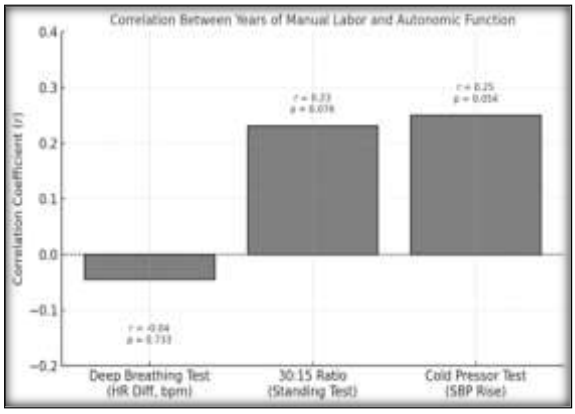
Table 4: Interpretation of Autonomic Function Test Results (n = 60)

Interpretation	Deep Breathing Test (HR Difference ≥15 bpm)	30:15 Ratio Test (Ratio ≥1.03)	Cold Pressor Test (SBP Rise ≥10 mmHg)
Normal	36 (60.0%)	51 (85.0%)	41 (68.3%)
Borderline	18 (30.0%)	6 (10.0%)	15 (25.0%)
Abnormal	6 (10.0%)	3 (5.0%)	4 (6.7%)

Correlation analysis between the duration of manual labor (in years) and autonomic parameters is shown in [Table 5]. The cold pressor test exhibited a weak positive correlation with years of manual labor (r = 0.250), with a borderline p-value of 0.054, suggesting a near-significant association. A similar positive trend was observed in the 30:15 ratio (r = 0.231, p = 0.076). However, no significant correlation was found between years of labor and deep breathing test performance (r = -0.045, p = 0.733), indicating no observable trend in parasympathetic modulation with increasing labor exposure in this cohort.

Table 5: Correlation Between Years of Manual Labor and Autonomic Function Parameters (n = 60)

Autonomic Function Parameter	Correlation Coefficient (r)	p-value	Interpretation
Deep Breathing Test (HR Difference, bpm)	-0.045	0.733	No correlation
30:15 Ratio (Active Standing Test)	0.231	0.076	Weak positive correlation (NS)
Cold Pressor Test (SBP Rise, mmHg)	0.250	0.054	Weak positive trend (borderline)



DISCUSSION

The present study was designed to evaluate autonomic nervous system (ANS) function among rural manual laborers using non-invasive, clinically applicable tests. Our findings reveal a trend of modest autonomic reactivity with a large proportion of subjects exhibiting borderline responses in both parasympathetic and sympathetic domains. These results reflect subtle shifts in autonomic balance that may be influenced by chronic occupational stress, physical workload, and adaptive cardiovascular modulation in physically active populations.

The mean heart rate variability (HRV) during deep breathing in our study was 16.81 ± 5.48 bpm, with 60% of participants falling in the normal range (≥15 bpm). This aligns with values reported in occupational studies among physically active males, such as the one by Chae et al., which found significantly reduced parasympathetic tone (as measured by RMSSD and LnHF) in emotional laborers with poor sleep quality compared to controls, indicating that both psychological and physical stressors can modulate HRV patterns[1]. However, the relatively preserved parasympathetic response in our cohort may be attributed to their higher levels of physical activity, which is known to support vagal tone.[2]

In terms of baroreflex integrity, the 30:15 ratio in our sample averaged 1.11 ± 0.08, with 85% of participants classified as normal (≥1.03). A study by Rapčan et al. on clinical applications of ANS testing reported similar values in physically robust subjects, reinforcing the notion that long-term engagement in manual labor may preserve short-term cardiac autonomic adjustments through repetitive orthostatic loading.[3] Furthermore, prolonged physical exertion is known to improve baroreflex sensitivity, an effect that may explain the high normal response rate in this test.[4]

The cold pressor test, which measures sympathetic vasoconstrictor response, showed a mean systolic rise of 12.22 ± 3.89 mmHg, with 68.3% of participants exhibiting normal sympathetic function (SBP rise ≥10 mmHg). This is comparable to studies in other occupational cohorts where the average SBP rise ranged from 10–14 mmHg in physically conditioned individuals.[5] Interestingly, the borderline and abnormal cold pressor responses observed in approximately one-third of our participants suggest possible blunting of sympathetic reactivity, potentially due to repeated sympathetic stimulation from daily physical work leading to adaptive desensitization or receptor downregulation.[6]

Our correlation analysis revealed a weak positive association between years of manual labor and both the 30:15 ratio (r = 0.231, p = 0.076) and cold pressor test (r = 0.250, p = 0.054), though statistical significance was narrowly missed. These trends suggest a possible cumulative effect of sustained physical activity on maintaining autonomic responsiveness, consistent with findings from Kočan et al., who emphasized that autonomic adaptation is a dynamic process influenced by both workload duration and physiological reserve.[7] No correlation was found between duration of labor and parasympathetic function (r = -0.045), indicating that other factors like age, sleep, and metabolic health may play more dominant roles in modulating vagal tone over time.[8]

The results of this study demonstrate that most rural manual laborers show adequate autonomic balance, particularly in baroreceptor and sympathetic domains, with some showing borderline parasympathetic function. These findings suggest that chronic manual labor, while physically demanding, may preserve or moderately influence autonomic regulation, though subtle adaptations may emerge over time. These insights highlight the importance of routine physiological screening in occupational populations, especially in rural settings where healthcare access is limited and chronic workload effects may go unrecognized.

CONCLUSION

This study demonstrates that rural manual laborers exhibit largely preserved autonomic function, with normal responses observed in the majority of participants for baroreflex and sympathetic tests, while a subset showed borderline parasympathetic reactivity. These findings suggest that long-term physical labor may support autonomic balance, particularly in the sympathetic domain, likely due to regular physical exertion. However, early borderline responses in parasympathetic function underscore the need for periodic screening and preventive measures to detect subclinical autonomic dysregulation in occupational groups.

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