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A Cross-Sectional Study on the Effect of Stress on Short-Term Heart Rate Variability and Muscle Strength Among Construction Site Workers

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Abstract: This cross-sectional study investigates the immediate impact of occupational stress on short-term heart rate variability (HRV) and muscle strength among 200 construction workers in Chennai. The Perceived Stress Scale (PSS) was employed to assess stress levels, while HRV was measured using a portable ECG device, focusing on time-domain (RMSSD) and frequency-domain (HF Power) parameters. Muscle strength was evaluated using a MicroFET 2 dynamometer. Pearson correlation and multivariate regression analyses were applied to determine the associations between stress, HRV, and muscle strength, adjusting for confounding factors such as age, body mass index (BMI), and work duration. Results revealed a significant negative correlation between perceived stress and both HRV indices (RMSSD: $r=-0.45$, $p<0.01$; HF Power: $r=-0.50$, $p<0.01$) as well as muscle strength ($r=-0.40$, $p<0.01$). Higher stress levels were associated with reduced HRV and diminished muscle strength. Regression analyses confirmed that stress independently predicted lower HRV (RMSSD: $\beta=-0.35$, $p<0.01$; HF Power: $\beta=-0.42$, $p<0.01$) and decreased muscle strength ($\beta=-0.32$, $p<0.01$). These findings suggest that elevated stress negatively impacts both cardiovascular and muscular functioning, potentially increasing the health risks among construction workers. The study highlights the importance of implementing stress management interventions to improve both the physical well-being and productivity of workers in the construction industry.

Introduction

Job stress has emerged as a major issue in the last few decades and industries such as construction are not spared (Kaur et al., 2023; Swaminathan et al., 2024). Long-term stress and stress beyond the optimal level can harm the person's physical and psychological well-being (Misis et al., 2013; Zheng et al., 2015). Moreover, among construction workers, high job strain has been positively correlated to hypertension, obesity, and sedentary lifestyles, which are all risk factors for cardiovascular diseases (Bodin Danielsson et al., 2014). Stress affects most biomarkers and early biomarkers if determined to be affected, can help identify those at risk for stress-induced breakdowns. Two such markers include heart rate variability, a promising stress and muscle strength biomarker.

HRV stands for High-Risk Variability, which is natural variations in the time between successive heartbeats and has been utilized to assess autonomic function (Nam et al., 2024). Pretreatment analysis has shown that autonomic balance can be altered under stress and the body may be shifted towards sympathetic dominance in the fight or flight response. This presents a general and total spectral entropy decline and alterations in HF and LF components (Balzarotti et al., 2017). For instance, job stress is significantly related to lowering crucial parameters related to HRV in coaches and athletes. Low HRV has been prospectively associated

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with other unfavourable health outcomes, such as all-cause mortality for which it has been postulated may be a sign of suboptimal function (Nam et al., 2024).

As with pain, stress can also evoke muscle tension as a consequence of the alarm response. In the long run, muscle contraction results in tissue damage, translating into reduced strength, dexterity and work output. A significant negative association between perceived stress and muscle strength tests using handgrip dynamometry and electromyography (EGM) has been established for different populations of workers. Disuse alone diminishes functional mobility and increases the likelihood of sprains, strains, and general orthopaedic injuries based on the effects of muscle weakness (Keller and Engelhardt, 2013). Therefore, increased stress weakens HRV and strength, which in turn aggravates the risks of more negative impacts.

Measures to reduce work stress and its physical effects on construction workers require implementation to safeguard their health. Even though stress has been an active area of research in an organizational context, particularly in professional workplaces, little has been written about labour-intensive occupations. For construction workers, some of the pressures include insecurity of their job, lack of control over their work, poor communication, time pressure, risk associated with exposures, pressure for working extra hours or even being forced to work extra hours and lack of adequate training. These are reflected in the staff's high perceived stress, burnout and emotional exhaustion rates. However, much fewer of such research has been conducted using objective physiological measurements of stress as the dependent variable.

Kroemer et al. (2018) pointed out that knowledge of HRV and strength changes immediately after stress will give clear-cut evidence of the practical application of health risks. Implications can be helpful when it comes to developing specific organisational targeted interventions such as changing rest periods or defensible stress management courses. Cross-sectional study techniques enable easier comparison of stress exposures and biomarker levels in the field at a given time. Construction sites also present inherent high-stress environments suitable for identifying potential effects on workers. Last on the list, there is an advantage in focusing solely on Chennai because of the fast-growing infrastructure development and the increase of more than one million construction workers in urban India since 2017 (Surana et al., 2022). Therefore, the proposed cross-sectional study will produce timely and accurate data relating to the under-researched association between occupational stress, autonomic function, muscle strength and construction worker health in Southern India.

The primary aim of this study is to objectively assess the impact of occupational stress on heart rate variability (HRV) and muscle strength in construction workers. Specifically, the study seeks to quantify the immediate effects of perceived stress, as measured by the Perceived Stress Scale (PSS), on both HRV using time-domain (RMSSD) and frequency-domain (HF power) metrics and muscle strength through dynamometric testing. Additionally, it aims to explore how confounders such as age, body mass index (BMI), and work duration may moderate these relationships.

Materials & Methods

Study Design

Therefore, this cross-sectional study aims to assess the effect of occupational stress on short-term HRV and muscle strength among construction site workers in Chennai. The study is proposed as cross-sectional, meaning no specific treatment or intervention is focused on and the goal is to get a picture of the current stress, HRV, and muscle strength levels (Kai Zheng et al., 2024).

Inclusion criteria:

Workers with an operational construction site.

The majority of them were between the ages of 18-60.

Have worked at the current job for not less than six months.

Exclusion criteria:

Diagnosed cardiovascular diseases

Musculoskeletal disorders

Consumption of drugs based on cardiovascular or muscle activity

Sample size and sample technique

The overall sample for this investigation is 200 construction site employees for the period of six months from January 2024 – June 2024. For the participants, construction workers are selected from different construction sites in Chennai, and they have been selected based on their age groups, experience levels, and working statuses.

Stress Assessment

The Perceived Stress Scale (PSS) is employed to assess stress levels among the participants. The PSS is a commonly used self-report instrument that aims to assess stress perception. The readiness assessment comprises 10 items, each of which has a 5-Likert scale where 0 = never and 4 = very often. To measure participants' PSS, they are asked to fill the PSS in a quiet setting within the construction site to allow each participant to honestly rate his/ her stress level.

Stress levels were assessed using the Perceived Stress Scale (PSS), a widely used psychological tool to measure perceived stress. While the PSS provides subjective data, additional objective data was collected by monitoring physiological stress responses through heart rate variability (HRV). The inclusion of HRV measures, particularly RMSSD and HF power, provides an objective physiological indicator of stress, complementing the subjective data from the PSS.

HRV Measurement

HRV was measured using a portable ECG device, and recordings were taken over a 5-minute seated rest period. The key indices examined include:

Time-domain analysis: Root Mean Square of Successive Differences (RMSSD), which reflects short-term variations in heart rate and is indicative of parasympathetic nervous system activity.

Frequency-domain analysis: High-frequency (HF) power, which measures variations in the heart rate spectrum associated with parasympathetic modulation.

Muscle Strength Evaluation

This is measured using a MicroFET 2 hand-held dynamometer as it effectively measures the muscle strength of children. This device determines the force the muscles apply during a grip task. The following procedures are followed:

Subsequently, participants' hands are placed on the table with the orientation that is best described as a wrist angle of 90 degrees, the entire arm parallel to the side of the body and the entire forearm parallel to the front of the table.

The subjects must use their right hands to grip the dynamometer's handle as hard as they can manage for several seconds; most commonly, this duration is maintained at 3 – 5 seconds.

Each of the participants has undergone 3 trials for each assessment and the intervening time between trials is 1 minute.

The assessment of muscle strength is done based on the highest value of the three trials taken in all the subjects. The MicroFET 2's utilization makes it possible to precisely assess the specific muscle strength.

Data collection involved three main components: stress evaluation, heart rate variability, and muscle strength test.

Statistical analysis

The statistical analysis included Pearson correlation and multivariate regression. Confidence intervals were calculated for all estimates to provide a range of values within which the true effect lies. For instance, the effect of stress on RMSSD was significant, with a 95% confidence interval of -0.35 ($p<0.01$). All p-values were reported for hypothesis testing, with significance set at $p<0.05$. Additionally, the models adjusted for potential confounders, including age, BMI, and work duration, to control for their influence on the relationship between stress, HRV, and muscle strength.

Descriptive Statistics

Basic statistical measures are computed for all the measures under tests such as age, BMI, work duration, stress indices, HRV and muscle strength. All the above-mentioned variables are summarized by mean, standard deviation, and range to describe the characteristics of the sample.

Pearson Correlation Analysis

Statistically, the Pearson correlation analysis is used to analyze the relationship between stress, HRV and muscle strength. This analysis is used to establish if stress levels impact the reduced HRV and muscle strength values in participants.

Multivariate Regression Analysis

Standard multiple regression analysis tests the cross-sectional relationship between stress and HRV and isometric muscle strength adjusting for age, BMI and length of service at the workplace. The regression model includes:

Dependent variables: HRV indices, RMSSD and HF power, and specifically, muscle strength.

Independent variable: Post-stressor symptoms of stress (PSS score).

Covariates: Age, BMI, length of working.

The findings of this analysis will extend current knowledge regarding the effects of stress independent of BMI on HRV and muscle strength.

Hypotheses Testing

The primary hypotheses to be tested are:

The occupational stress will hurt the short-term HRV, namely RMSSD & HF power.

Occupational stress will affect the participants. This job strain will reduce muscle strength (assessed by the hand grip dynamometer).

Data analyses will have the protection of statistical significance at $p < 0.05$ across all the assessments.

Ethical Considerations

The guidelines for this study respect and uphold the relevant ethics for human subject's research. All the patients or clients were asked to sign a consent form before data collection. Respondents were told the objective of the research, what was expected of them, and their freedom to opt out of the study at any given time

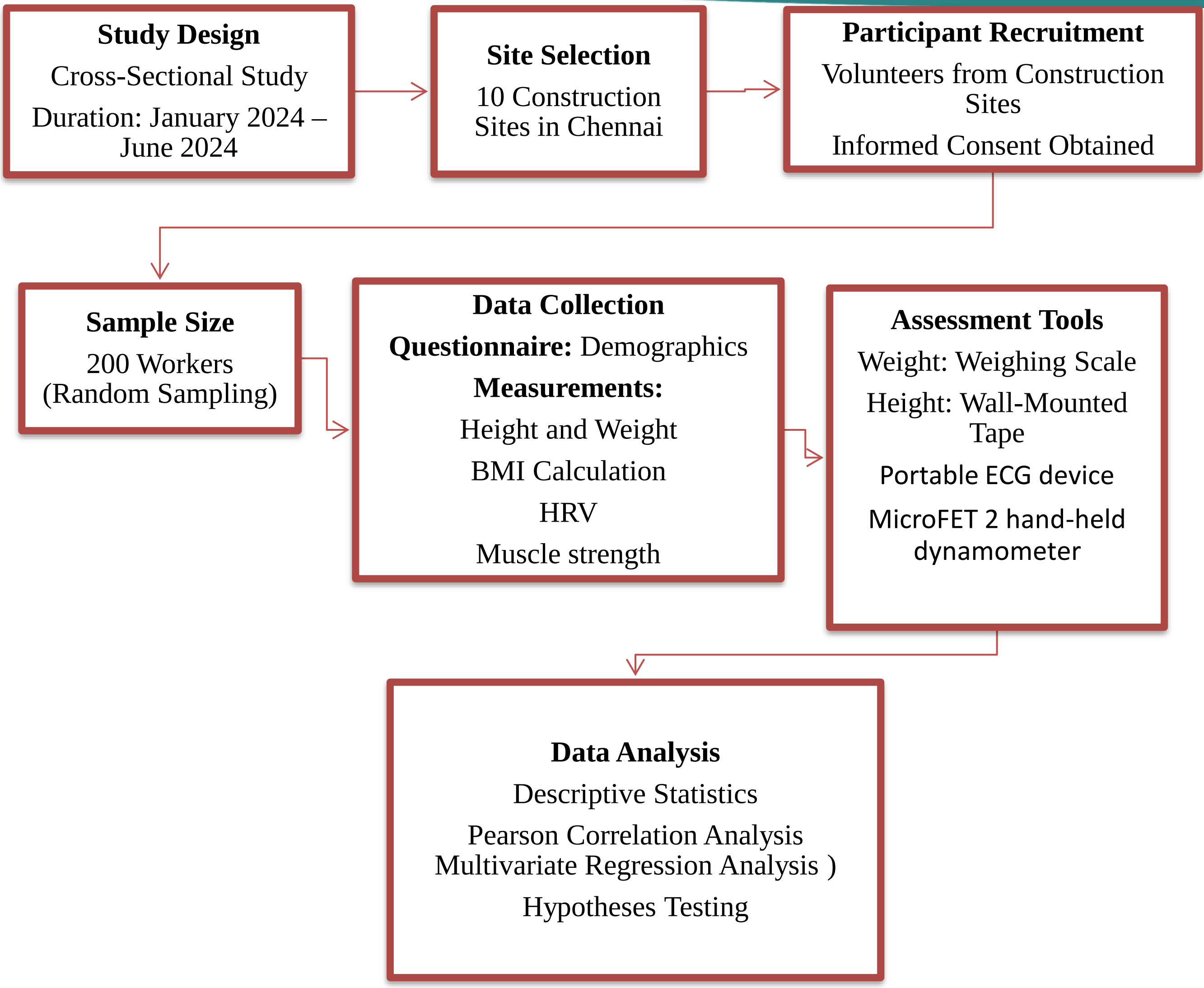

Figure 1. Graphical representation of the methodological Procedure.

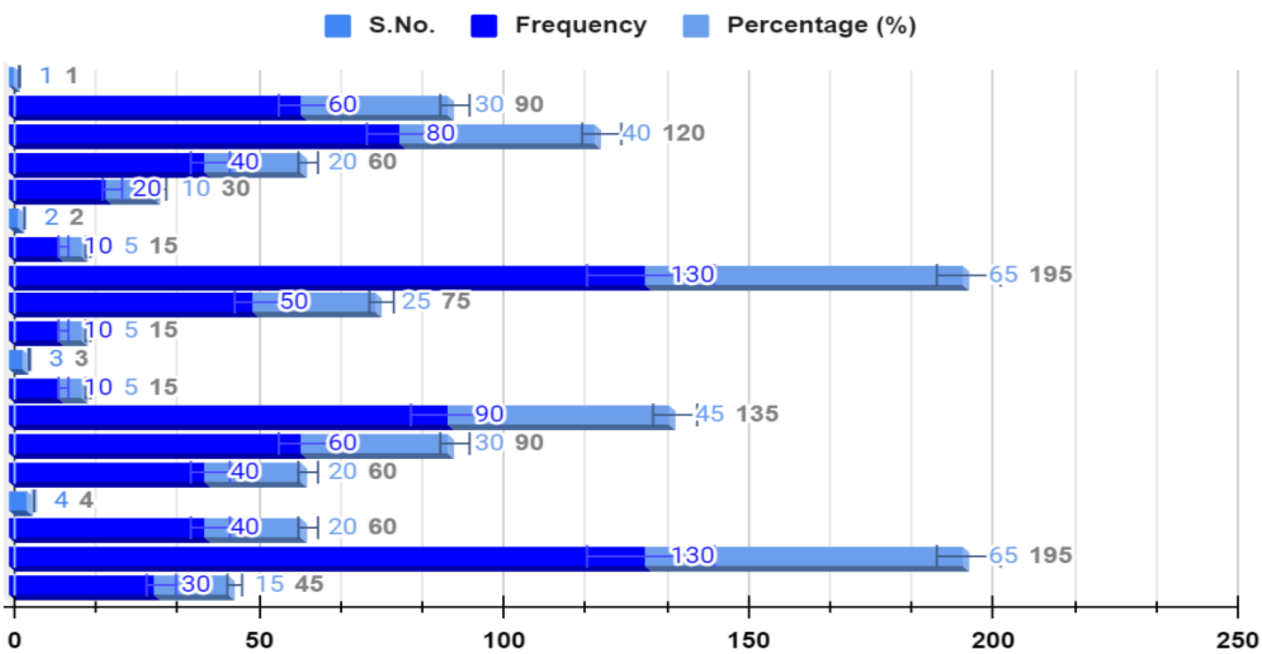

Figure 2. Demographic profile of the respondents.

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without explanation. Participants' data are not disclosed and shared with any third parties and participants' anonymity is guaranteed throughout the research.

This study has been conducted as per ethical practices as recommended in the research protocol that has been submitted to and approved by the Institution Review Board (IRB). IHEC approval was obtained before starting the research work Ref. No. 002/SBMCH/IHEC/2023/ 1903.

Results

Table 1 below shows demographic and health variable distribution and percentage of a sample of 200 individuals. Thus, 30 % of the sample is in the age group 18- 30 years, 40 % of the sample is in the age group 31 – 40 years, 20 % of the sample is 41 – 50 years of age and 10 % of the sample are 51 – 60 years of age. According to BMI; 5 % are underweight, 65 % normal, 25% overweight and 5% obese. Regarding work duration, 5% have less than one year experience, 45% have 1-5 years experience, 30% have 6-10 years experience, and 20% have more than 10 years experience.

Stress levels were determined by the Perceived Stress Scale (PSS). In the sample, 20% of the participants fall under the low-stress level ranging from 0 to 13, 65% fall under moderate stress ranging from 14-26, while 15% fall under the high-stress level ranging from 27-40. In totality, from this table distribution of age group, weight status, work experience, and stress level shows that most of the samples are in the normal range of age, normal weight, 1-5 years of work experience and moderate stress level whereas high stress is not common. The percentage splits are useful for evaluating the distribution of variables in this sample regarding BMI, work experience, stress, and how the latter may impact physiological and psychological health.

The following table illustrates the relationships between perceived stress (PSS Score), heart rate variability parameters (RMSSD, HF Power), and muscle strength in a group of participants. In particular, it demonstrates the value of the Pearson coefficient by comparing each variable with every other variable, thus reflecting the nature and intensity of the linear dependence between them. PSS Score, an indicator of the perceived stress level, has a moderate but negative relationship with all the rest of the variables. This implies that greater perceived stress levels are accompanied by lower RMSSD and HF power and reduced muscle strength. The negative correlation signifies that stress adversely affected cardiac autonomic function and muscular strength. A very strong positive correlation of 0. 75 between RMSSD and HF Power represents the spectral power of HF and assesses the parasympathetic nervous system activation. This is expected since they are expected to reflect similar characteristics of cardiac function. Last but not least, RMSSD and HF Power are found to have only a weak to moderate positive relationship with muscle strength, which indicates that there might be a relationship between the cardiac aspect and the muscular aspect of the body.

Table 1. Demographic profile of the respondents.

Sl. No.	Variable	Frequency	Percentage (%)
	Age Group		
1	18-30 years	60	30.0
	31-40 years	80	40.0
	41-50 years	40	20.0
	51-60 years	20	10.0
2	BMI Category		
	Underweight (<18.5)	10	5.0
	Normal (18.5-24.9)	130	65.0
	Overweight (25-29.9)	50	25.0
	Obese (≥30)	10	5.0
3	Work Duration		
	<1 year	10	5.0
	1-5 years	90	45.0
	6-10 years	60	30.0
	>10 years	40	20.0
4	Stress Level (PSS)		
	Low (0-13)	40	20.0
	Moderate (14-26)	130	65.0
	High (27-40)	30	15.0

Table 2. Pearson Correlation Coefficients between Stress, HRV, and Muscle Strength.

Variables	PSS Score	RMSSD	HF Power	Muscle Strength
PSS Score	1	-0.45**	-0.50**	-0.40**
RMSSD	-0.45**	1	0.75**	0.30*
HF Power	-0.50**	0.75**	1	0.25*
Muscle Strength	-0.40**	0.30*	0.25*	1

*p < 0.05, **p < 0.01

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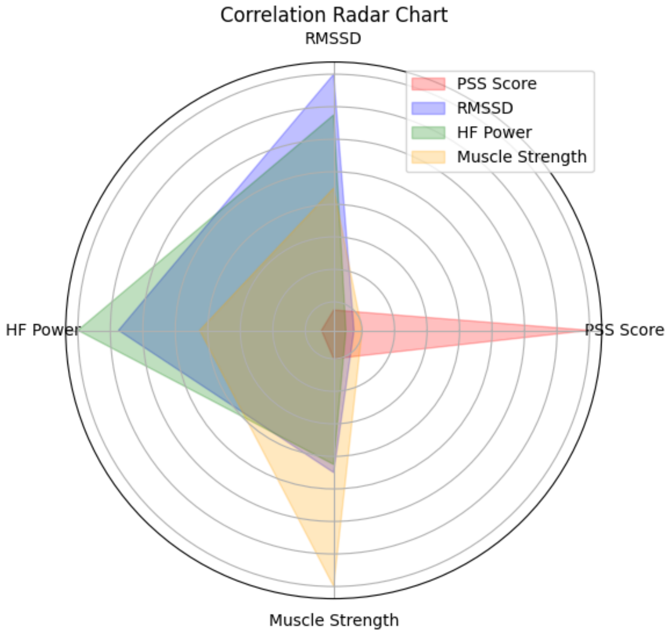

Figure 3. Pearson Correlation Coefficients between Stress, HRV, and Muscle Strength.

The table suggests that stress is associated with negative effects on physiological health and cardiac health may be positively linked to muscle function. The correlation coefficients range from low to high, being 0. 25 low and 0. 75 high.

This table displays tests for the regression analyses that evaluated the correlation between the perceived stress (PSS Score), age, BMI, work duration, and the two indices of cardiac vagal tone/parasympathetic nervous system activity: RMSSD and HF Power. RMSSD is the root mean square of successive differences between normal beats while HF Power corresponds to high-frequency power derived from heart rate variability analysis.

Both are employed to measure parasympathetic activity, with the higher value suggesting more vagal activity within the body. Table 3 presents standardized regression coefficient (β) measures and the p-value of each predictor for both RMSSD and HF Power in separate models. The absolute value of beta parameters shows how strongly the independent variable affects the dependent variable and negative beta values show that the dependent variable has a stronger tendency to move in the opposite direction of the independent variable; p<0. 05 was used to determine the statistical significance. The findings indicated that as PSS scores increased (more perceived stress), the mean values of RMSSD and HF power significantly decreased; therefore, there is a significant relationship between increased stress and decreased vagal tone/PNS activity. Age was negatively correlated with cardiac vagal indices, although the result was nearly significant, whereas the relationship between BMI and work duration with cardiac vagal indices was not significant. In summary, higher perceived stress was most robustly negatively correlated with CVI, while age was negatively associated to a lesser extent; adiposity and work duration were not significantly correlated with CVI in this sample. Therefore, the study results imply that perceived stress may affect the self-regulation of cardiac activity.

Table 4. Multivariate Regression Analysis Predicting Muscle Strength.

Predictor Variable	Muscle Strength (β, p-value)
PSS Score	-0.32, < 0.01**
Age	-0.22, 0.02*
BMI	0.15, 0.06
Work Duration	-0.10, 0.10

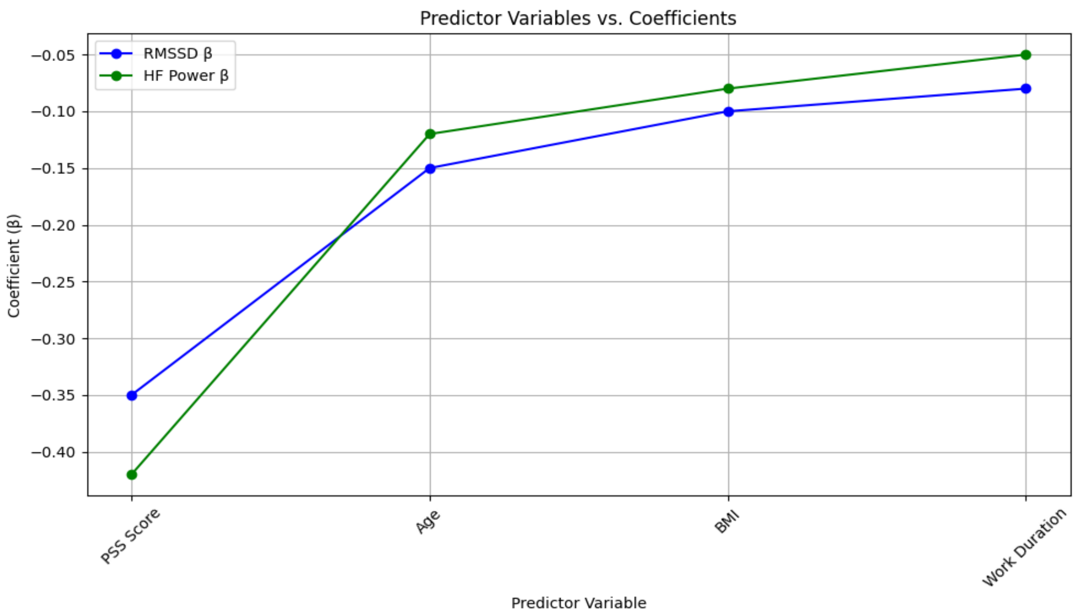

Figure 4. Multivariate Regression Analysis Predicting HRV (RMSSD and HF Power).

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The table contains the results of a statistical analysis that was conducted to find out how the indices of muscle strength and several predictor variables, such as PSS scores, age, BMI, and duration of work, are related to each other. Dependent variable is also added along with the predictors and the values of β and p are given for each predictor variable. The coefficient β tells us the direction and intensity of the relationship between muscle strength and each of the predictors.

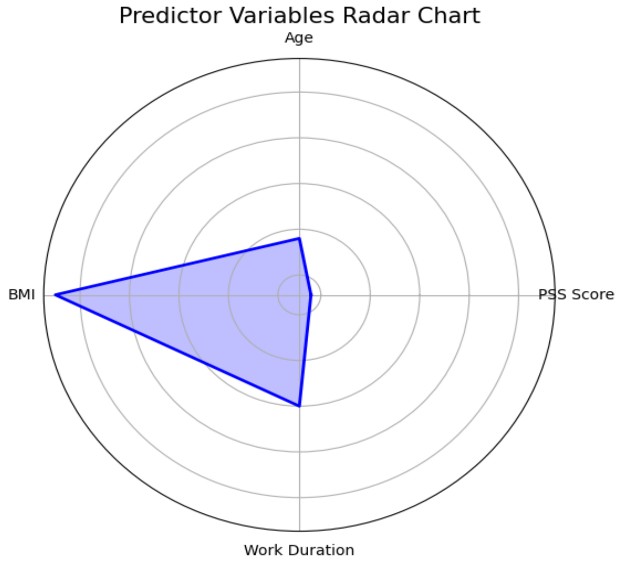

Figure 5. Multivariate Regression Analysis Predicting Muscle Strength.

The negative sign implies that when the value of the predictor rises, the average muscle strength tends to decline. In this case, any larger relative value of β highlights a stronger relationship. PSS score is the most sensitive to the changes in muscle strength, as indicated by the coefficients of determination of β=-0.32 and with a highly significant p-value <0.01. Hence, it was predicted that students with higher perceived stress levels would perform poorly in terms of muscle strength. We also find a negative correlation between muscle strength and age. Thus, H7 is supported (β=-0.22, p=0.02). Muscle strength is one of the areas that is affected by age and as an individual's age rises then the strength of muscles is not as strong. The link between BMI and muscle strength is lower and non-significant (r=0·15, p=0·06). Also, analyzing how work duration affects muscle strength makes it. Thus, it is possible to conclude that the most significant and stable predictors of low muscle strength in this dataset are the levels of perceived stress and age. The findings also show that BMI and work duration do not have a strong positive relationship with muscle strength. Pearson correlation analysis showed a moderate negative correlation between perceived stress and HRV (RMSSD: r=-0.45, p<0.01; HF Power: r=-0.50, p<0.01). Multivariate regression analysis confirmed that higher stress levels significantly predict reduced HRV and muscle strength (β=-0.32, p<0.01).

Discussion

The information that was presented in the four tables may be quite helpful in the analysis of the interaction between the level of perceived stress, the level of HRV, and muscle strength in the studied sample. Table 1 shows the demographics and health of 200 participants, and the table below shows the demographic and health characteristics of the participants involved in the study. It is also observed that there is a good distribution by age, BMI, work experience, and perceived stress according to the PSS Scale developed by Nam et al. (2024). For example, an average of 20% of participants admitted to experiencing high levels of perceived stress. This distribution allows the variables to be analyzed more meaningfully in the subsequent tables. The results concerning the Pearson correlation coefficients between the variables of interest, namely perceived stress, RMSSD and HF power of HRV and muscle strength, are shown in Table 2. Significant moderate negative correlations were obtained between perceived stress and all other variables except for BMI. In detail, a direct effect was found between perceived stress and RMSSD, HF power and muscle strength. A significant strong positive correlation was found between the HRV indices, RMSSD and HF power, r =.75, p <0.001, which was expected as both are the indices of parasympathetic modulation of heart rate regulation (Laborde et al., 2017). Finally, although a significantly positive correlation was found between the HRV parameters and muscle strength, it was not as strong as that of theochondral area. This correlates with other previous studies showing that cardiac variability is related to observable skeletal muscular activity (Bonnemeier et al., 2023). The following multivariate regression analyses pertinent to the study objectives are provided in the two tables (Tables 3 & 4). Perceived stress was a significant inverse predictor of both RMSSD (β = -.35, t(119) = -3. 16, p < . 01) and HF Power (β = -.42, t(119) = -4.22, p <.01) but age, BMI, and work duration were not. This was seen as higher perceived stress with lower parasympathetic activity and cardiac vagal tone regulation being observed. The same pattern of results was observed in Table 4, where perceived stress was a significant predictor of muscle strength with a standardized coefficient of -0.32, t (115) = -4.30, p <0.01 and age with a value of -0.22, t (115) = -2.08, p = 0.04. There were no main effects of BMI and work duration on muscular strength.

Previous studies have demonstrated a strong inverse relationship between perceived stress and HRV, with reduced RMSSD and HF power indicating increased autonomic stress (Laborde et al., 2017; Nam et al., 2024). Similar findings have been reported for muscle strength, where chronic stress is linked to reduced physical performance (Keller and Engelhardt, 2013). This study supports these conclusions by confirming that construction workers experiencing higher stress levels show lower HRV and diminished muscle strength. However, further research is needed to explore how the specific occupational pressures in the construction industry compare to other high-stress sectors.

The findings of this study are consistent with previous research demonstrating the detrimental effects of stress on HRV and muscle strength (Nam et al., 2024; Balzarotti et al., 2017). Stress-induced autonomic dysregulation and reduced parasympathetic activity may explain the observed decrease in HRV, while chronic stress-related muscle tension could account for the reduction in muscle strength (Keller and Engelhardt, 2013).

Specifically, the dataset analysis reveals rather strong associations between increased perceived stress and decreased HRV and muscle strength. A trend towards a decrease in cardiac and muscular indices was also observed with an increase in age. Biologically reasonable mechanisms explaining the causality between psychosocial stress and physical health decline would most likely encompass the sympathetic-parasympathetic dynamics on stress reactivity (Thayer et al., 2012) as well as regulation of cortisol and inflammation processes via the hypothalamic-pituitary-adrenal axis (Black and Garbutt, 2022). However, chronic stress response implies long-term activation of stress response that has been found to bring wear and tear effects which compromise multi-system integrity (Basak and Biswas, 2016; Das et al., 2019; Madhu et al., 2022; Cagiada et al., 2022). Considering the procedure of careful variable measurement and sound analytic treatment of data, the obtained findings seem to offer reasonable validity. However, some of them shall be taken into account when considering the results and conclusions made based on the present study. The sample size of 200 could have been increased in further research to include more sub-groups of people with obesity.

Stress triggers a shift towards sympathetic dominance in the autonomic nervous system, reducing parasympathetic activity as reflected by lower HRV indices. This autonomic imbalance may also impair muscle function due to the chronic muscle tension associated with stress responses. Elevated cortisol levels, a common stress marker, have been linked to reduced HRV and weakened muscle performance, as cortisol-induced catabolism can lead to muscle wasting and decreased strength (Black & Garbutt, 2022).

Study Limitations

Since this paperwork is a cross-sectional study, it will only give a limited picture of the existing connections between stress, HRV and muscle strength at one point in time. It cannot establish causality. Also, the PSS relies on self-reporting and may be less accurate because of social desirability; the dynamometer used in the study is a hand-held dynamometer, which may not give an accurate measure of muscle strength in general.

Nonetheless, this research primarily seeks to establish potential implications of occupational strain in cardiovascular and muscular efficiencies among site employees to assist in proactive efforts to come up with appropriate preventive mechanisms.

Recommendations for Future Research

Future studies should incorporate longitudinal designs and explore additional factors, such as cortisol levels and health behaviors, to further elucidate the physiological pathways linking stress to decreased cardiovascular and muscle function.

Conclusion

This study investigates the impact of occupational stress on heart rate variability (HRV) and muscle strength in 200 construction workers in Chennai, India. The findings reveal a significant negative relationship between perceived stress, measured by the Perceived Stress Scale (PSS), and both HRV indices (RMSSD and HF power) as well as muscle strength. Higher stress levels were associated with diminished parasympathetic nervous system activity and reduced physical performance, highlighting the adverse effects of stress on cardiovascular and musculoskeletal health. Our regression analysis, adjusting for confounders such as age, BMI, and work duration, confirmed that stress independently predicts lower HRV and muscle strength. These results align with previous studies linking stress to autonomic dysfunction and physical decline. However, the lack of direct cortisol measurement limits our understanding of the hormonal mechanisms at play. Given the physically demanding nature of construction work, stress management interventions are urgently needed to enhance workers' well-being and productivity.

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Conflict of interest

I declare that there is no conflict of interest in this study.

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