American Journal of
Biomedical Science & Research

www.biomedgrid.com
ISSN: 2642-1747

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Sex Specific Relationships Between Resting Heart Rate and Handgrip Strength in College Students

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To Cite This Article: *Nathan J Anderson, Myra J Bloom, Emily C Castile, Scarlet R Jost, Andrew SID Lang*, et al. Sex Specific Relationships Between Resting Heart Rate and Handgrip Strength in College Students. Am J Biomed Sci & Res. 2025 25(4) AJBSR.MS.ID.003347,* **DOI:** 10.34297/AJBSR.2025.25.003347

Received: January 20, 2025; **Published:** January 27, 2025

Abstract

Background: This study aimed to explore the relationship between Handgrip Strength (HGS) and Resting Heart Rate (RHR) among college-aged students, with a hypothesis of an inverse relationship moderated by sex.

Methods: Data were collected from 609 participants, measuring HGS, RHR, height, and weight. Multiple linear regression models were used to assess the association between RHR and HGS, accounting for sex as a moderating factor. The significance level was set at $\alpha \leq 0.05$.

Results: RHR was found to be a significant predictor of HGS, with a stronger negative association observed in males.

Conclusions: These results suggest sex-specific physiological differences in the relationship between RHR and HGS, with potential implications for personalized strength and conditioning programs targeting young adults.

Keywords: Physical strength, Strength conditioning, Fitness assessment, Sex differences

Plain English Summary

This study looks at the relationship between Resting Heart Rate (RHR) and Handgrip Strength (HGS) in college students. RHR is a common measure of heart health, and HGS is an easy way to assess overall body strength. We wanted to see if there is a link between these two factors and whether this relationship is different for men and women. We measured the RHR and HGS of 609 college students. The results showed that students with lower RHR tend to have stronger handgrip strength, but this connection is stronger in men than in women. Men, on average, had a lower RHR and greater handgrip strength than women. These findings suggest that heart rate and strength are linked in young adults, and this link is influenced by gender. The study highlights the importance of considering these differences when designing exercise and strength training programs. Coaches and fitness trainers can use this information to develop personalized health and fitness plans that consider individual heart rates and strength levels for both men and women.

Highlights

i. **Sex-Specific Differences:** A stronger inverse relationship between Resting Heart Rate (RHR) and Handgrip Strength (HGS) is observed in males compared to females.

ii. **Physiological Correlations:** Both height and weight significantly predict HGS, with RHR playing a unique role, particularly in males.

iii. **Health and Fitness Insights:** The study emphasizes the potential for using HGS as a non-invasive predictor of cardiovascular health in college students.

iv. **Tailored Training Programs:** Results suggest the importance of sex-specific approaches to strength and conditioning interventions for young adults.

v. **Novel Contribution:** This is one of the few studies exploring the RHR-HGS relationship in a healthy, young adult population, offering practical implications for personalized fitness assessments.

Background

Resting Heart Rate (RHR) is a vital health indicator, representing the severity or development of various diseases and predicting mortality in healthy individuals [7,13,21]. Studies have shown that increased RHR is associated with higher risks of heart failure, cardiovascular disease, and coronary heart disease, indicating increased strain and workload on the heart [5,9,15]. Despite its significance, the relationship between RHR and physical performance, specifically Handgrip Strength (HGS), has not been extensively studied in young, healthy populations. *Nealen, et al.,* [12] examined the RHR of healthy college-aged adults and found that males generally had lower RHR than females. The study indicated that total exercise hours per week were a better predictor of RHR than aerobic exercise hours alone. This finding aligns with *Zanuto, et al.*, [20], who reported that physical activity positively correlated with lower RHR in adolescents, with sports-related activities significantly reducing RHR. HGS is a well-established predictor of total body strength and has been linked to various health outcomes. *Leyk, et al.,* [10] and *Sağiroğlu, et al.,* [17] found significant gender differences in HGS, with men consistently exhibiting greater strength than women. *Silva, et al.,* [18] and *Liu, et al.,* [11] further connected HGS to Cardiovascular Health (CVH), noting that higher HGS is associated with better heart rate recovery and lower cardiovascular disease incidence. Recent studies have suggested a potential link between HGS and RHR. *Andrade, et al.,* [1] showed that hand grip exercises could significantly lower RHR, with gender-specific differences in the effectiveness of various interventions. Furthermore, research on aging adults consistently demonstrates that lower RHR correlates with higher HGS and better overall health [14,19]. However, similar investigations in younger, healthy populations are limited, and the interplay between RHR and HGS in younger populations, particularly college students, is underexplored.

The effects of gender on HGS were also studied by *Koley, et al.,* and *Singh, et al.,* [8]. Their study consisted of 151 male and 152 female Indian college students. They found that males had approximately double the HGS of females. They also observed that hand breadth and hand length were correlated with right HGS in males. Height and weight were found to correlate with HGS for male and female students, with males showing higher mean values for height, weight, hand breadth, and hand length. *Chatterjee, et al.,* and *Chowdhuri, et al.,* [4] found that across all age groups, the right hand had greater endurance compared to the left hand. They also noted that the right and left hand GS was positively correlated with weight, height, and body surface area. In our study, we hypothesize that RHR is a significant predictor of HGS among college students, with the relationship moderated by sex. Specifically, we expect a more pronounced negative association between RHR and HGS in males compared to females. This hypothesis is grounded in previous findings that highlight gender differences in both RHR and HGS and their associations with physical activity and CVH. Understanding the relationship between RHR and HGS can have practical implications for strength and conditioning practices. Tailoring training programs to account for sex-specific differences and incorporating RHR monitoring could enhance the effectiveness of interventions aimed at improving physical performance. By providing evidence-based insights, our study aims to contribute to the development of more personalized and effective fitness assessments and training regimens for young adults.

Methods

Experimental Approach to the Problem

The purpose of this study was to determine if a relationship existed between HGS and RHR in a cohort of college-aged students attending a mid-western university. It was hypothesized that an inverse relationship existed between HGS and RHR in the sample studied. To test this hypothesis, HGS and RHR data were collected from 609 participants, with the sample divided into male and female groups to explore potential sex-based differences. The study design was structured to effectively test the developed hypotheses. HGS was chosen as the dependent variable due to its established role as a predictor of overall body strength and its association with various health outcomes. RHR was selected as the independent variable because of its significance as a health indicator and its potential influence on physical performance.

Subjects

The data for this study were collected from 616 primarily first-year college students, aged 18 years or older, enrolled in health and fitness classes during the Fall 2022 and Spring 2023 semesters. To maintain the focus on the traditional college-age demographic, we excluded 7 participants over the age of 26 from the dataset prior to conducting statistical analyses. This resulted in a final sample of 609 participants, aged between 18 to 26 years; median age 19 [22]. We performed additional analyses incorporating these participants to evaluate the impact of excluding these seven older individuals on our study's outcomes. These analyses confirmed that their exclusion did not modify the study's results in any way. The average characteristics of the sample were: age=19 years, height=1.7 meters, weight=72.4 kilograms, RHR=67 Beats Per Minute (BPM), and MaxAvgHGS=78.06 kilograms. For males, the averages were: age=19 years, height = 1.77 meters, weight=78.9 kilograms, RHR=64 BPM, and MaxAvgHGS=99.5 kilograms. For females, the averages were: age=19 years, height=1.64 meters, weight=68.1 kilograms, RHR=69 BPM, and MaxAvgHGS=64 kilograms. To investigate potential sex-based differences across various physiological and demographic variables, we divided the data into male (N=241; 39.6%) and female (N=368; 60.4%) groups. This approach was informed by insights from previous research [3] and the hypothesis that significant differences could exist between these groups across all study variables. RHR data were obtained from fitness trackers worn by all freshmen at the institution as part of their health and physical exercise requirements. All students are also required to enrol in a health and physical exercise course every semester. HGS scores were recorded during strength training class labs. Participants provided informed consent for all data collected, and the results were explained as part of the class content.

Procedures

HGS data and RHR values were collected from 31 sections of a freshman health and fitness class and four weight training classes at a mid-western private university during the 2022-2023 academic year. All freshmen were enrolled in a, required of all students, full-year health and fitness class consisting of 12 labs per semester. These labs were designed to teach students how to create and implement a personal fitness program that included aerobic activities, flexibility training, strength training, stress management, and nutrition. Fitbit activity trackers were used to provide students with information on their progress toward achieving activity goals of 10,000 steps per day and 150 active minutes per week. In addition to steps and active minutes, data on RHR were also recorded and electronically transferred from Fitbit to the institution's course management system.

During the strength training labs, HGS data were collected by trained technicians using a Jamar Plus handgrip dynamometer, calibrated according to the procedures outlined by the National Institute of Standards and Technology. Prior to testing grip strength, age, gender, and dominant hand were recorded, and the grip position was adjusted for hand size. Data from students with hand injuries were excluded from the analysis. Subjects were tested in a seated position, with the arm held next to the body, the elbow flexed at 90 degrees, and the wrist extended between 0 and 30 degrees. Each subject performed three maximal trials per hand, alternating between right and left hands, with a one-minute rest between each trial. Upon completion of the participant's testing, the test average, standard deviation, and coefficient of variation were calculated automatically by the dynamometer and recorded for further analysis. The participants were informed of how their values compared with established norms [6].

Statistical Analyses

The primary outcome measure was MaxAvgHGS, representing the highest average HGS from three trials across both hands, to account for potential bias due to hand dominance or injury. Other variables measured included weight, height, and sex, as these are known confounding variables with HGS. We kept height and weight separate instead of using the composite Body Mass Index (BMI) score or allometric scaling, as previous work had shown that results were better this way [2]. All data were analyzed using R 4.3.1 [16] and various commonly used packages to test for statistically significant differences between medians and models. The statistical significance threshold was set at $\alpha \leq 0.05$. The study's statistical power exceeded 0.80 for detecting medium effect sizes (Cohen's d=0.5) given our sample size of N=609, and the reliability of the dependent measures was confirmed with Intra-Class Correlations (ICCs) exceeding 0.85.

Results

This study aimed to explore the relationship between RHR and HGS among college students, considering potential confounding factors such as sex, height, and weight. To select the most appropriate statistical tests for assessing differences between the two groups, Shapiro-Wilk tests were initially conducted to evaluate the normality of each variable's distribution within the male and female subsets. The tests indicated non-normal distributions for the majority of variables ($p<0.05$), with the exceptions being MaxAvgHGS in males ($p=0.405$) and females ($p=0.851$) as well as RHR in females ($p=0.444$), suggesting that non-parametric methods were generally more appropriate for our analysis. Considering the majority non-normality of distributions of the dataset's variables, Wilcoxon rank-sum tests were utilized to identify any significant differences in the medians of each variable by sex. Our analysis identified statistically significant differences in the medians of MaxAvgHGS, weight, height, and RHR between male and female participants ($p<0.05$), with males displaying, on average, higher MaxAvgHGS, weight, and height, but lower RHR values than their female counterparts. These results highlight the existence of sex-based physiological differences within our dataset. Despite males having a higher median age (19 yrs.) compared to females (18.5 yrs.), this age difference was not statistically significant ($p=0.206$). See Table 1 for a summary of median values and Interquartile Ranges (IQR). See Figure 1 for density plots of AvgMaxHGS and RHR by sex with median lines, illustrating the significant difference in both median and IQR values for these variables.

Table 1: Median values and Interquartile Ranges (IQR) for the dataset variables by sex.

	Males (N = 241)		Females (N = 368)		
Measure	median	IQR	median	IQR	Wilcoxon (p)
MaxAvgHGS (lbs.)	97.6	28	64.2	16.9	< .001
RHR (bpm)	63	9	69	11	< .001
weight (kg)	76.7	17.2	65.3	20	< .001
height (m)	1.78	0.1	1.65	0.08	< .001
age (yrs.)	19	2	18.5	2	0.206

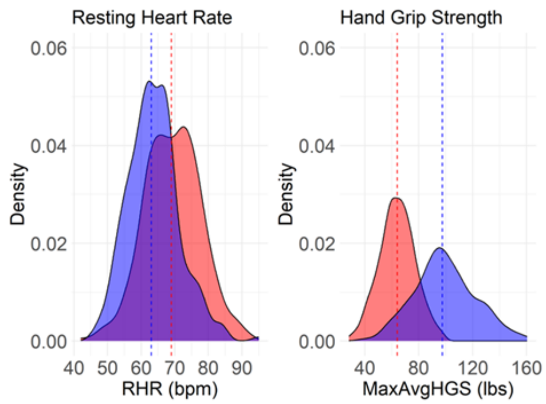

Figure 1: Density plots for Maximum Average Hand Grip Strength (MaxAvgHGS) and RHR by sex (blue for males, red for females). Median lines are included to underscore the statistically significant differences between the sexes. The larger interquartile range (dispersion) of MaxAvgHGS among males is also evident, underscoring larger variations in strength within the male demographic.

Regression Analysis

Multiple Linear Regression (MLR) analysis was conducted to explore the relationship between maximum average hand grip strength (MaxAvgHGS) and RHR among college students, with adjustments for variables such as weight, height, and sex. These variables were included in the model due to their individual correlations with both MaxAvgHGS and RHR, see Figure 2, as well as the significant differences in their medians by sex, ensuring they served as meaningful predictors rather than confounding factors. This analysis aimed to uncover the complex interplay of factors influencing HGS across the different sexes. For a visual representation of the pairwise correlations among the model variables, see Figure 2. This approach offers a nuanced understanding of how physiological variables collectively impact HGS in a sex-specific manner (Figure 2).

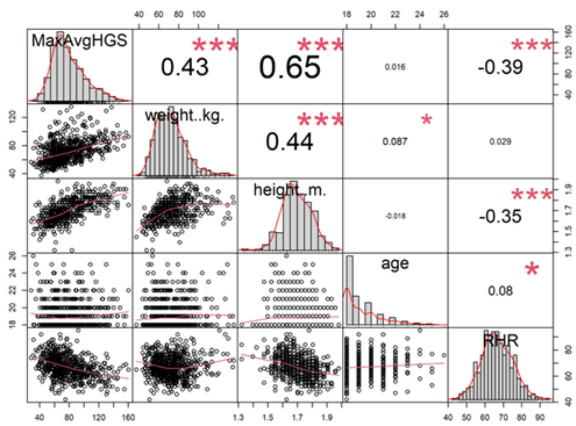

Figure 2: A correlation matrix illustrating the pairwise relationships between MaxAvgHGS, weight, height, age, and RHR. Histograms and scatter plots are situated along the diagonal and lower triangle to represent the distribution of individual variables and their bivariate relationships, respectively. The Pearson correlation coefficients are indicated in each cell, with significance levels marked by asterisks directly above (*p<0.05, **p<0.01, ***p<0.001). The matrix visually emphasizes the varying strengths of linear associations, showcasing notably positive correlations between MaxAvgHGS and both weight and height, alongside a significant negative correlation with RHR.

The overall multiple linear regression model, incorporating height, weight, and sex as controlled variables, demonstrated a significant relationship between MaxAvgHGS and RHR, even after adjusting for the other variables, see Equation 1. The model accounted for approximately 60% of the variability in MaxAvgHGS (N=609; adj-R-squared=0.5962). Specifically, RHR (β=-0.52797, p<0.001), height (β=48.32915, p<0.001), weight (β=0.30927, p < 0.001), and sex (β=22.45776, p<0.001) were all identified as significant predictors of MaxAvgHGS. The negative beta coefficient for RHR suggests that higher RHRs are associated with lower maximum average HGS. Similarly, positive beta coefficients for height and weight indicate that taller individuals with higher body weights tend to have greater HGS. The positive beta coefficient for sex reflects the fact that males are, on average, stronger than females (HGS: +22.5 lbs.).

(1) $AvgMaxHGS = 0.28 - 0.53 \cdot RHR + 48.33 \cdot height + 0.31 \cdot weight + 22.46 \cdot sex(male)$

Separate regression models for males and females were created to highlight sex-specific relationships. The male-specific model (N=241), which accounts for 27.57% of the variance in MaxAvgHGS (adjusted R-squared=0.2757), identified RHR (β=-0.93264, p<0.001), height (β=55.13661, p<0.01), and weight (β=0.48988, p<0.001) as significant predictors, as shown in Equation 2. This suggests a stronger inverse relationship between RHR and MaxAvgHGS for males compared to what was found in the general population, along with the positive correlations between MaxAvgHGS and both height and weight being confirmed again.

(2) $Males: AvgMaxHGS = 22.15 - 0.93 \cdot RHR + 55.14 \cdot height + 0.49 \cdot weight$

In comparison, the female-specific model (N=368), which has a smaller adjusted R-squared of 0.1584 than that of the male-specific model, similarly identified RHR (β=-0.25838, p<0.01), height (β=44.53941, p<0.001), and weight (β=0.1761, p<0.001) as significant predictors, see Equation 3. Notably, there was a less pronounced inverse relationship between RHR and MaxAvgHGS in females compared to males, suggesting a possible interaction between sex and physiological factors influencing HGS.

(3) $Females: AvgMaxHGS = -3.13 - 0.26 \cdot RHR + 44.54 \cdot height + 0.18 \cdot weight$

Our findings from the standard linear models led us to investigate further, where we discovered a significant interaction between RHR and sex affecting MaxAvgHGS. The interaction term, RHR *sexM, has a negative correlation (β=-0.63103, p<0.001), indicating that the negative association between RHR and MaxAvgHGS is stronger in males than females, as illustrated in Figure 3. See Equation 4 for the full model (adj-R-squared=0.6051), where all factors are statistically significant (RHR, p=0.0037; all other factors, p<0.001). This nuance highlights the importance of considering sex-specific models when examining the determinants of HGS.

(4) $AvgMaxHGS = -17.41 - (0.3 + 0.63 \cdot sex(male)) \cdot RHR + 50.04 \cdot height + 0.29 \cdot weight + 63.92 \cdot sex(male)$

An ANOVA comparison between the full model (Equation 1) and the interaction model (Equation 4) reinforces the significance of this interaction. The results indicate a significant improvement in model fit upon incorporating the interaction term, with a significant F-statistic (F=14.693, p<0.001). This statistical evidence strongly supports the addition of the interaction term for a more accurate and nuanced model of HGS determinants, highlighting the critical role of sex differences in the association between RHR and MaxAvgHGS (Figure 3).

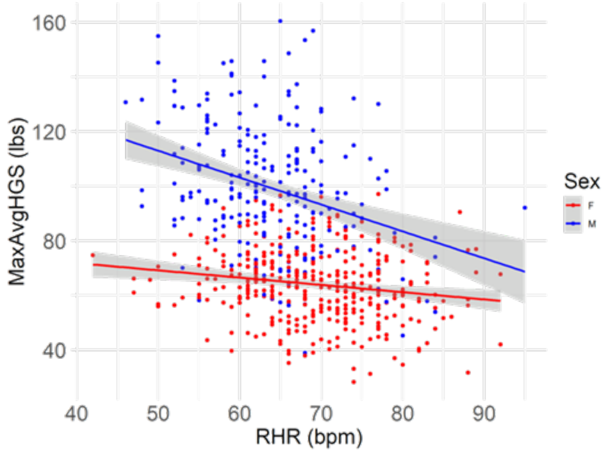

Figure 3: A scatterplot of Maximum Average Handgrip Strength (MaxAvgHGS) versus RHR by Sex. Each point represents an individual's MaxAvgHGS plotted against their RHR, with females depicted in red and males in blue. Solid lines represent the linear regression fit for each group, indicating the trend in the relationship between RHR and MaxAvgHGS. Shaded areas around the regression lines show the 95% confidence intervals. The plot also illustrates the different slopes of the relationship for females and males, indicating an interaction between sex and the effect of RHR on MaxAvgHGS.

In summary, our analysis provides compelling evidence that RHR is a significant predictor of HGS among college students, even when accounting for potential confounding factors such as sex, height, and weight. Notably, the inclusion of an interaction term between RHR and sex further elucidates the complex dynamics at play, revealing a more pronounced negative association between RHR and MaxAvgHGS in males compared to females. This interaction underscores the necessity of adopting sex-specific models to accurately assess the determinants of HGS, highlighting the nuanced interplay between physiological variables and physical performance.

Discussion

Our study aimed to explore the relationship between RHR and HGS among college-aged students, with a focus on potential sex-based differences. Our results indicate a significant inverse relationship between RHR and HGS, with notable variations between males and females. Consistent with previous findings, we observed that males exhibited higher HGS and lower RHR compared to females [4,8]. The study by *Nealen, et al.,* [12] aligns with our results, showing lower RHR in males. The significant inverse relationship between RHR and HGS observed in our study supports the notion that a lower RHR is indicative of better overall CVH, which in turn, enhances physical performance. This relationship was more pronounced in males, suggesting that sex-specific physiological factors play a crucial role in influencing HGS. *Andrade, et al.,* [1] also noted gender-specific differences in the effectiveness of interventions aimed at reducing RHR through hand grip exercises, which is consistent with our observations. Moreover, our study confirms the correlation between HGS and anthropometric measures such as height and weight [4,8]. These findings emphasize the importance of considering these variables when assessing physical strength and CVH.

Conclusion

In conclusion, our study demonstrates a significant inverse relationship between RHR and HGS among college-aged students, with sex-specific differences influencing this relationship. These findings contribute to the existing literature by highlighting the importance of considering sex-specific physiological factors when assessing the determinants of physical strength and CVH. Further research is needed to explore these relationships in diverse populations and develop targeted interventions to improve both HGS and CVH.

Practical Applications

The results of this study have practical implications for strength and conditioning practices. HGS can serve as an inexpensive and non-invasive predictor of CVH. Coaches and practitioners can use HGS as a tool for monitoring CVH and tailoring training programs accordingly. Interventions for individuals with low HGS could potentially improve CVH risk factors and reduce the likelihood of future disease. Since HGS is positively correlated with height and body surface area, strength and conditioning coaches can utilize this information to design effective training regimens for athletes in sports requiring significant strength and force, such as baseball and softball. Fitness trainers and exercise specialists can benefit from these findings by creating personalized training programs that enhance overall strength and reduce RHR, thereby promoting better health outcomes. It is crucial to employ sex-specific models that account for physiological variables and biomechanical disparities to accurately evaluate factors affecting an athlete's HGS.

Declarations

Ethics Approval and Consent to Participate

All data were acquired from class activities and approved by Oral Roberts University's Institutional Review Board (IRB)–IRB: 14-F2018 & Amendment to 14-F2018. The study protocol included appropriate informed consent procedures, ensuring ethical compliance. Eligibility criteria for subject selection were based on age (18 years or older) and enrollment in health and fitness classes, with descriptive information such as age, height, body mass, RHR, and HGS documented. Dietary controls and supervision were not part of this study.

Consent for Publication

None.

Availability of Data and Materials

The datasets generated and analysed during the current study are available in the figshare repository, https://doi.org/10.6084/m9.figshare.26947720.v1

Funding

None.

Authors Contributions

NA assisted with statistical analysis, interpretation of results, and manuscript preparation. MB contributed to data management, literature review, and manuscript preparation. EC assisted with background research and manuscript preparation. SJ contributed to data collection, provided expertise on health and fitness measures, and assisted with manuscript preparation. AL oversaw the study design, supervised data analysis, and critically reviewed the manuscript. NM assisted with the interpretation of physiological data and contributed to manuscript editing. PN and SS contributed to background research and final editing of the manuscript. VG and ET assisted with statistical analysis, presentation of results, and manuscript preparation. EV and CW provided support with data visualization, figure preparation, and manuscript preparation. All authors read and approved the final manuscript.

Acknowledgements

The authors would like to thank the HLSS department faculty for their invaluable cooperation, granting access during class hours to facilitate measurements, and for their unwavering encouragement and support for this research.

Competing Interests

None.

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