ORIGINAL ARTICLE

Differences in the psychophysiological response between normal weight and overweight young recreational athletes in strength training

Álvaro Bustamante-Sánchez. *Department of Sports Sciences. Faculty of Medicine, Health and Sports. European University of Madrid. Madrid, Spain.*
Sergio de la Torre-Gómez ✉ . *Department of Sports Sciences. Faculty of Medicine, Health and Sports. European University of Madrid. Madrid, Spain.*
Vicente Javier Clemente-Suárez. *Department of Sports Sciences. Faculty of Medicine, Health and Sports. European University of Madrid. Madrid, Spain.*
Research Group on Culture, Education and Society. University of La Costa. Barranquilla. Colombia.

ABSTRACT

Background: Strength training is widely recognized for its benefits in young recreational athletes, yet limited research has explored its effects on heart rate variability (HRV) across different body compositions. This study aimed to analyse the autonomic modulation differences between normal-weight and overweight recreational athletes during strength training. Methods: A total of 63 male recreational athletes (23.8 ± 3.6 years, 174.9 ± 8.2 cm, 70.8 ± 11.7 kg) were categorized into normal-weight (Body Mass Index < 25) (N = 38) and overweight (Body Mass Index > 25) (N = 25) groups. Participants performed three sets of 10 repetitions at 70% 1RM for both squats and bench press. HRV parameters, including RMSSD, SDNN, and PNN50, were measured before, during, and after training. Additionally, heart rate (HR), rate of perceived exertion (RPE), and strength levels were assessed. Results: HR significantly increased during training in both groups, with a greater post-exercise HR elevation observed in the normal-weight group. HRV parameters (RMSSD, SDNN, PNN50) decreased significantly during training in the normal-weight group, indicating greater autonomic stress. RPE increased post-exercise in both groups, while the overweight group demonstrated higher baseline strength levels. Conclusion: Strength training induced acute autonomic stress in both groups, with greater HRV suppression observed in normal-weight athletes, suggesting a higher physiological demand. In contrast, overweight athletes displayed better baseline strength levels and potentially greater adaptability to strength training. These findings highlight the need for individualized training prescriptions based on body composition to optimize performance and recovery in recreational athletes.
Keywords: HRV, Strength, Recreational athletes, Physiological response, BMI.

Cite this article as:
Bustamante-Sánchez, A., de la Torre-Gómez, S., & Clemente-Suárez, V. J. (2026). Differences in the psychophysiological response between normal weight and overweight young recreational athletes in strength training. *Journal of Human Sport and Exercise, 21*(1), 1-10. https://doi.org/10.55860/d6921037

✉ **Corresponding author.** *Universidad Europea de Madrid. Department of Sports Sciences. Faculty of Medicine, Health and Sports.*
E-mail: Sergiodlt91@outlook.es
Submitted for publication July 23, 2025.
Accepted for publication September 05, 2025.
Published October 02, 2025.
Journal of Human Sport and Exercise. ISSN 1988-5202.

doi: https://doi.org/10.55860/d6921037

INTRODUCTION

Recently there has been an increase in the number of young athletes who focus on strength training, as well as an increase in training focused on improving heart rate variability (Nuzzo, 2020; Thompson, 2022). The benefits of strength training are notable in the young athlete population. Strength training not only improves muscle strength, but it also contributes to bone health, body composition, and enhances injury prevention (Faigenbaum et al., 2013). Strength training has shown to be beneficial to the mental health of young athletes, increasing self-confidence, self-esteem and body image, and reducing levels of anxiety and depression (Robinson et al., 2023). Also, it's been shown an improvement in functional capacity and even help prevent the development of chronic metabolic diseases like type II diabetes and obesity (Granacher et al., 2016). Not only does it help with metabolism and function, but it's also been linked to changes in the autonomic nervous system and Heart Rate Variability (HRV).

The stress of the autonomous nervous system can be measured by HRV, which is a non-invasive method to assess the prevalence of the sympathetic or parasympathetic branches to better adapt to different trainings (Selig et al., 2004). Also, strength training has proven to be an interesting method for modulating heart rate variability and thus avoiding potential risks to overall cardiovascular health (Güngör et al., 2024).

Historically, aerobic training is the most studied in the acute response for HRV values, however, the findings on modulation of vagal tone through strength training do not reflect positive results (Cooke & Carter, 2005). These effects depend on several factors, such as training intensity, exercise selection, cognitive workload and the individual's previous experience in physical activities (Díaz-García et al., 2023; Heffernan et al., 2007). Interest in studying the relationship between strength training and HRV is also due to growing evidence that reduced HRV is associated with an increased risk of cardiovascular accidents and mortality, especially in individuals with chronic diseases such as hypertension or heart failure (Buchheit & Gindre, 2006), and in overweight or obese individuals (Reena Tiwari et al., 2021). Identifying effective interventions to improve or maintain healthy HRV is crucial for the prevention and management of these conditions.

Recent studies have observed that strength training programs performed at moderate to high intensity can increase HRV, suggesting an improvement in the balance between sympathetic and parasympathetic activity (Lee et al., 2024). Strength training in overweight individuals (BMI > 25) is related to HRV through the relationship of several mechanisms. One is the reduction of systemic inflammation and oxidative stress, which are common in overweight individuals and may contribute to autonomic dysfunction (Esco et al., 2010). In addition, strength training improves insulin sensitivity and endothelial function, factors that influence autonomic modulation and HRV (Ashor et al., 2015).

Studies evaluating strength training traditionally use methods such as 1RM (one maximum repetition) to establish loads, but some authors suggest the possibility of monitoring strength training loads through pulsometers and heart rate variability (Buchheit, 2014; Stanley et al., 2013).

Assessing the acute responses of the autonomic nervous system during strength training provide interesting results that would help to discover whether strength training can generate adaptations of the cardiac system. This study aimed to analyse differences in autonomic modulation between normal weight and overweight young recreational athletes during a strength training. We hypothesized that both groups would decrease their HRV values due to the stress of the strength training, and that heart rate variability would be lower in the overweight group.

METHODS

Participants

We analysed N = 63 male recreational athletes (23.8 ± 3.6 years. 174.9 ± 8.2 cm. 70.8 ± 11.7 kg), which were divided in two groups: normal weight group (BMI < 25, N = 38) and overweight group (BMI > 25, N = 25). Subjects were stratified according to their Body Mass Index (BMI), determined by calculating BMI as weight in kilograms divided by the square of height in meters (kg/m²), using anthropometric data obtained during the baseline assessment. This study is quasi-experimental research. Convenience sampling was used, as participants were recruited among volunteers that agreed to participate in the study. The experimental procedures were explained to all the participants, following the Declaration of Helsinki, and approved by the Ethics Committee of the University (CIPI/18/74).

Procedure

All the participants performed a strength training following the procedures of previous research (Bustamante-Sánchez et al., 2018; Bustamante-Sánchez & Clemente-Suárez, 2020). 1 RM (maximum repetition) tests were conducted between 09:00 a.m. to 12:00 p.m., under the same environmental conditions (temperature 25–26ºC, humidity 52–54%). Participants were asked to conduct the training session with at least 8 h of sleep, hydrated (drink at least 500 ml of liquid between wake up and the test), and having a standardized breakfast composed of fruit juice, milk, and cereals. The participants verbally agreed to have followed these rules prior to the strength intervention.

The estimation of 70% of 1 RM was calculated on a separate day, prior to baseline testing, for all two exercises.

A 15min rest was allowed before every 1 RM assessment. Training session started with a standardized warm up for 15 min. Before and after warming up participants conducted the flicker fusion test.

After warming up, participants performed 3 sets composed of the following exercises:

- 10 repetitions of squat at 70% of the 1 RM.
- 10 repetitions of bench-press at 70% 1 RM.

Before and after the 1 RM assessment, the following parameters were analysed:

(1) Body mass (to the nearest 0.1 kg) was measured by a bio impedance analyser (InBody 720, Biospace Co. Ltd., Seoul, South Korea).
(2) Body height (to the nearest 1 cm) was measured by a portable stadiometer (SECA, Leicester, UK).
(3) Cortical arousal through the Critical Flicker Fusion Threshold (CFFT) in a viewing chamber (Lafayette Instrument Flicker Fusion Control Unit Model 12,021) following the procedures conducted in previous studies (Bustamante-Sánchez & Clemente-Suárez, 2020).
(4) Isometric handgrip strength by a grip dynamometer (Takei Kiki Koyo. Japan). (Bustamante-Sánchez & Clemente-Suárez, 2020).
(5) Horizontal jump with hands on waist.
(6) Jump tests (Squat Jump, Countermovement Jump, and Abalakov jump) were assessed through the Optojump system (Microgate Engineering, Bolzano, Italy).
(7) Subjective perceived stress was assessed with a 0-100 scale, like in previous studies (Bustamante-Sánchez et al., 2018; Bustamante-Sánchez & Clemente-Suárez, 2020).

(8) Rate of perceived exertion (RPE) in a 6-20 rank was assessed through the Borg scale (Borg, 1982).

(9) Heart Rate Variability (HRV) through a Polar v800 heart rate monitor (Polar Electro Oy, Finland) validated to record RR function to analyse heart rate variability (HRV) (Giles, Draper & Neil, 2015), by the Kubie's HRV software (University of Kuopio. Kuopio, Finland) following procedures of previous research (Bustamante-Sánchez et al., 2021).

The data obtained was divided into three segments, which are used to summarize the entire procedure. The first segment was designated the 'pre-test' and consisted of measurement in basal state without intervention. The second segment was designated 'during the strength tests' and consisted of measurements during strength tests. The third segment was designated the 'post-test' and consisted of measurement after 5 minutes of rest, during which an attempt was made to return to the basal state.

Statistical analysis

The IBM SPSS statistical package (version 26.0; SPSS, Inc. Chicago, Illinois) was used to analyse the data. Normality assumptions were checked with a Kolmogorov-Smirnov test. Descriptive statistics were presented as mean and standard deviation. A mixed ANOVA test, with three repeated measures for HRV tests and two repeated measures for the arousal and physical tests was used. Moreover, one factor (BMI group) was added to compare the effect of the test, the effect of the BMI group, and the interaction among the type of test, and the effect of the BMI group. To analyse pairwise comparisons, a Bonferroni post hoc test was used. The level of significance for all the comparisons was set at $p < .05$. For the HRV analysis we used the average of the intervals.

RESULTS

Table 1 shows the heart rate variability differences among BMI groups and pre, during, and post measurements. Heart rate (HR) was higher during strength training (108.5 ± 22.6; 102.3 ± 20.8) than in the pre-measurements (91.3 ± 15.4; 90.1 ± 15.99) in both groups. HR was also higher in the normal weight group (BMI < 25) during the post-test (97.4 ± 17.8) than during the pre-measurement (90.1 ± 15.99). RMSSD, SDNN and PNN50 were lower during strength training than during the pre-test in the normal weight group (31.2 ± 15.8; 43.8 ± 19.5; 8.26 ± 5.90 vs 41.9 ± 22.3; 58.3 ± 32.5; 12.7 ± 13.7). SDNN was lower in the post-test than in the pre-measurement. HF was higher for the normal weight group when compared to the overweight group during the pre-test (23.4 ± 8.86 vs 15.6 ± 2.85).

Table 2 shows the arousal and physical differences among BMI groups and measurement instants. RPE was higher in the post measurements than in the pre-tests in both BMI groups ($p < .05$). Strength levels were higher in the overweight group than in the normal weight group during the pre-tests ($p < .05$).

DISCUSSION

This study aimed to analyse differences in autonomic modulation between normal weight and overweight recreational athletes during a strength training. The findings supported the initial hypothesis: both groups decreased their HRV values during the training showing greater stress. When comparing pre- and post-exercise results in groups with different BMI, the findings suggest that, although strength exercises improve physical performance, BMI may influence perceived exertion and jumping performance.

Table 1. Heart-rate variability results.

	Pre				During				Post				Strength and BMI effect		
	BMI > 25		BMI < 25		BMI > 25		BMI < 25		BMI > 25		BMI < 25				
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	F	*p*-value	η^2
HR	91.3‡‡	15.4	90.1‡‡, ‡‡‡	15.9	108.5‡	22.6	102.3‡	20.8	102.1	24.2	97.4‡	17.8	0.296	.745	.008
RMSSD	41.9	22.3	50.6‡‡	38.2	35.3	22.7	31.2‡	15.8	44.3	28.8	36.3	21.6	1.027	.363	.028
SDNN	58.3	32.5	63.3‡‡, ‡‡‡	26.9	48.4	18.4	43.8‡	19.5	58.4	28.2	48.8‡	20.8	1.084	.344	.029
PNN50	12.7	13.7	17.4 ‡‡	17.1	11.6	14.6	8.26‡	5.90	13.1	13.6	12.8	16.9	1.102	.338	.030
SD1	31.4	14.2	48.1	57.9	26.1	16.1	25.8	17.0	32.8	19.3	26.7	15.1	0.871	.423	.024
SD2	86.4	40.6	79.7	33.6	67.3	39.3	58.7	27.9	80.1	35.3	66.6	26.0	0.119	.888	.003
SD1/SD2	0.39	0.08	0.97	2.13	0.37	0.09	0.87	2.53	0.44	0.14	0.95	1.84	0.003	.997	.000
LF (n.u.)	81.0	8.35	76.1	9.07	76.7	13.4	76.7	15.6	76.1	14.4	77.8	12.7	0.612	.545	.017
HF (n.u.)	15.6*	2.85	23.4*	8.86	21.0	11.3	20.7	9.45	21.8	14.2	20.2	12.4	2.261	.112	.061
LF/HF	5.30	1.06	4.50	4.70	4.90	3.28	0.49	2.67	5.81	5.82	5.40	3.15	0.061	.941	.002

*Note. BMI: Body Mass Index. M: Mean. SD: Standard Deviation. t: t test. HR: Heart Rate. RR: R-R interval. RMSSD: Root mean square of successive RR interval differences. SDSD: Standard Deviation of the differences between successive NN intervals. SDNN: Standard deviation of NN intervals. PNN50: Percentage of successive RR intervals that differ by more than 50ms. SD1: Poincaré plot standard deviation perpendicular to the line of identity. SD2: Poincaré plot standard deviation along the line of identity. SD1/SD2: Ratio of SD1-to-SD2. LF: Low-frequency band (0.04–0.15 Hz). HF: High-frequency band (0.15–0.4 Hz). LF (n.u.): Relative power of the low-frequency band (0.04–0.15 Hz) in normal units. HF (n.u.): Relative power of the high-frequency band (0.15–0.4 Hz) in normal units. ‡ Difference with pretest (p < .05). ‡‡ Difference with Strength period (p < .05). ‡‡‡ Difference with post-test (p < .05). *Differences between BMI groups (p < .05).*

Table 2. Arousal and physical results.

	Pre				Post				Strength and BMI effect		
	BMI > 25		BMI < 25		BMI > 25		BMI < 25				
	M	SD	M	SD	M	SD	M	SD	F	*p*-value	η^2
Flicker (hz)	38.6	4.51	38.9	4.32	38.8	3.64	40.6	10.6	0.219	.642	.004
Stress (0-100 rank)	27.3	17.1	25.3	17.9	45.6	18.9	49.1	21.0	0.344	.560	.007
RPE (6-20 rank)	7.11‡‡	1.45	7.18‡‡	2.85	14.3‡	3.00	13.4‡	4.31	0.453	.504	.009
Strength (kg)	50.5*	11.6	41.6*	9.29	49.5	12.2	42.6	9.87	1.934	.171	.040
SJ (cm)	30.3	8.35	30.5	8.15	29.6	8.30	30.8	8.39	0.385	.538	.008
CMJ (cm)	33.5	8.18	33.6	7.93	32.5	7.86	34.2	7.73	1.263	.267	.027
ABK (cm)	38.1	8.76	38.9	10.9	35.5	8.05	39.9	10.7	3.434	.070	.071

*Note. BMI: Body Mass Index. M: Mean. SD: Standard Deviation. RPE: Rate of Perceived Exertion. SJ: Squat Jump. CMJ: Countermovement Jump. ABK: Abalakov Jump. ‡ Difference with pre-test (p < .05). ‡‡ Difference with post-test (p < .05). * Differences between BMI groups (p < .05).*

The results of this study revealed a significant reduction in heart rate variability (HRV) during strength training in both normal-weight and overweight athletes, highlighting an acute autonomic stress response. RMSSD, SDNN, and PNN50 values were notably lower during the training session compared to pre-exercise levels, with a more pronounced decrease observed in the normal-weight group. These findings align with previous studies indicating that strength training acutely suppresses parasympathetic activity while increasing sympathetic dominance, leading to decreased HRV (Kingsley & Figueroa, 2016). Although previous research has suggested that overweight individuals tend to have lower baseline HRV due to impaired autonomic function (Lopes et al., 2007), our results did not show a significantly different HRV response between groups. This may be attributed to the fact that the participants were recreational athletes who had undergone previous training adaptations that could mitigate potential baseline autonomic differences. Additionally, strength training has been reported to improve HRV over time, particularly in individuals with lower baseline values, through mechanisms such as enhanced endothelial function and reduced inflammation (Selig et al., 2004). Comparing our findings to prior studies, Figueiredo et al. (2015) (Figueiredo et al., 2015) found that HRV suppression during strength training is dependent on the training load, with higher intensities leading to more pronounced reductions. Similarly, Melo et al. (2008) (Melo et al., 2008) observed that eccentric strength training in healthy older adults led to HRV reductions, suggesting that training modality plays a role in autonomic responses. However, some studies have reported that strength training does not lead to significant HRV changes, particularly when performed at moderate intensities (Lemos et al., 2018). These discrepancies may stem from differences in participant demographics, training protocols, and HRV measurement methods.

It was also found that perceived stress levels increased in both groups after the strength exercise protocol. This is in line with the findings of other studies which indicate that high-intensity training, such as strength exercises, may induce a temporary increase in perceived stress due to the physical and psychological demand of the effort (Atakan et al., 2021). Both groups experienced an increase in perceived stress, and there were no significant differences between the two groups. Walker et al. (2020) (Walker et al., 2020) found similar results. They reported that strength exercise increases cortisol levels and perceived stress, and these effects are not modulated by BMI.

Perceived exertion (RPE) increased markedly after the exercise protocol in both groups, with post-exercise values that were higher than pre-exercise values. However, no significant differences were found between the two groups. This finding is consistent with previous results indicating that, although individuals with higher BMI may experience higher cardiovascular and respiratory load during exercise, subjective perception of exertion tends to increase similarly between individuals with different BMI when adjusting exercise intensity (Haff et al., 1997). Strength levels, measured through the handgrip strength test, showed significant differences between both groups before the exercise protocol, with the overweight group showing higher strength levels. After the training session, no significant differences were observed in both groups. Results suggest that individuals with higher BMI, who may have greater absolute muscle mass (despite the absence of empirical data on muscle mass levels at this stage, this hypothesis remains conjectural), tend to show higher levels of strength (Tomlinson et al., 2016). We probably did not find significant differences between the two groups due to the hours of exercise practiced by the subjects. This is a hypothesis, and as such, it remains provisional pending further evidence. Being accustomed to a certain level of training, the subjects may already be adapted to these physical demands regardless of their BMI. The absence of significant post-exercise differences could indicate that, despite differences in absolute strength, the ability to adapt to strength training is similar between the two groups when controlling relative training intensity (Holloszy & Coyle, 1984). Measures of jumping performance (Squat Jump, Countermovement Jump and Abalakov Jump) showed no significant differences between the two groups. These results agree with studies that have shown that jumping ability is closely related to power and explosive strength but may be less efficient in individuals with higher BMI due to the greater body mass they must displace during jumping (Ben Brahim et al., 2023). Both groups showed improvements in jump heights, which affirms the idea that strength training is effective in improving jumping power regardless of BMI (Paavolainen et al., 1999).

The main limitation of this study was the lack of variables of body composition and the hours of training practiced by the subjects. It would be beneficial to include additional variables in future studies to assess body composition, as this also plays an important role in cardiovascular and autonomic modulation health. In addition to BMI, it would be beneficial to consider the ratio of skeletal muscle mass to body fat percentage when assessing physical fitness.

Practical applications

The findings of this study highlight important practical implications for strength training programming, particularly regarding its autonomic impact on recreational athletes with different body compositions. The observed decrease in HRV during training suggests that strength exercises induce acute autonomic stress, which should be considered when designing training programs to optimize recovery and performance. Coaches and practitioners can use HRV monitoring as a tool to assess training load and ensure adequate recovery, preventing excessive autonomic fatigue, especially in normal-weight athletes who exhibited greater HRV reductions. Moreover, given that overweight athletes demonstrated better strength levels and potentially greater adaptability to strength training, individualized training programs could leverage this advantage by incorporating progressive overload strategies tailored to their physiological responses. The use of HRV-based biofeedback and wearable heart rate monitors may also help athletes regulate their training intensity and recovery strategies more effectively. Incorporating strength training into structured fitness programs for individuals with different BMI classifications can contribute to long-term cardiovascular and neuromuscular adaptations. Future research should focus on the chronic effects of strength training on HRV across diverse populations to further refine training prescriptions and optimize health and performance outcomes.

CONCLUSION

This study aimed to analyse differences in autonomic modulation between normal-weight and overweight young recreational athletes in strength training. The results showed that both groups experienced a reduction in HRV during training, indicating increased autonomic stress. However, the normal-weight group exhibited a greater decrease in HRV, suggesting a higher physiological demand. Additionally, the overweight group demonstrated higher pre-test strength levels, indicating better baseline muscular capacity. These findings suggest that body composition influences autonomic and performance responses to strength training, with overweight athletes potentially exhibiting better adaptability. Future research should further explore the chronic effects of strength training on HRV to optimize training strategies based on BMI classifications.

AUTHOR CONTRIBUTIONS

ÁB-S: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing – original draft, writing – review & editing. SDLT: conceptualization, investigation, methodology, software, writing – original draft, writing – review & editing. VC-S: conceptualization, investigation, validation, writing – original draft, writing – review & editing.

SUPPORTING AGENCIES

This study has been financed by the Universidad Europea de Madrid, through an internal competitive project with codes 2024/UEM25 and 2024/780.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

REFERENCES

Ashor, A. W., Lara, J., Siervo, M., Celis-Morales, C., Oggioni, C., Jakovljevic, D. G., & Mathers, J. C. (2015). Exercise Modalities and Endothelial Function: A Systematic Review and Dose-Response Meta-Analysis of Randomized Controlled Trials. Sports Medicine, 45(2), 279-296. https://doi.org/10.1007/s40279-014-0272-9

Atakan, M. M., Li, Y., Koşar, Ş. N., Turnagöl, H. H., & Yan, X. (2021). Evidence-Based Effects of High-Intensity Interval Training on Exercise Capacity and Health: A Review with Historical Perspective. International Journal of Environmental Research and Public Health, 18(13). https://doi.org/10.3390/ijerph18137201

Ben Brahim, M., Sal-de-Rellán, A., Hernaiz-Sánchez, A., Yasin, H., & García-Valverde, A. (2023). The relationships between body mass index, reciprocal ponderal index, waist-to-height ratio, and fitness in young adult males. Frontiers in Psychology, 14. https://doi.org/10.3389/fpsyg.2023.1250913

Borg, G. A. (1982). Psychophysical bases of perceived exertion. Medicine and Science in Sports and Exercise, 14(5), 377-381. https://doi.org/10.1249/00005768-198205000-00012

Buchheit, M. (2014). Monitoring training status with HR measures: Do all roads lead to Rome? Frontiers in Physiology, 5. https://doi.org/10.3389/fphys.2014.00073

Buchheit, M., & Gindre, C. (2006). Cardiac parasympathetic regulation: Respective associations with cardiorespiratory fitness and training load. American Journal of Physiology-Heart and Circulatory Physiology, 291(1), H451-H458. https://doi.org/10.1152/ajpheart.00008.2006

Bustamante-Sánchez, Á., & Clemente-Suárez, V. J. (2020). Psychophysiological Response to Disorientation Training in Different Aircraft Pilots. Applied Psychophysiology and Biofeedback, 45(4), 241-247. https://doi.org/10.1007/s10484-020-09478-9

Bustamante-Sánchez, Á., Gil-Cabrera, J., Tornero-Aguilera, J. F., Fernandez-Lucas, J., Ramos-Campo, D. J., & Clemente-Suárez, V. J. (2021). Effects of Hypoxia on Selected Psychophysiological Stress Responses of Military Aircrew. BioMed Research International, 2021, 1-7. https://doi.org/10.1155/2021/6633851

Bustamante-Sánchez, Á., Loarte-Herradón, V. M., Gallego-Saiz, J. F., Trujillo-Laguna, T., & Clemente-Suárez, V. J. (2018). Psychophysiological response of fighter aircraft pilots in normobaric hypoxia training. Archivos de Medicina del Deporte, 35(2), 99-102. https://doi.org/10.1080/00140139.2018.1510541

Cooke, W. H., & Carter, J. R. (2005). Strength training does not affect vagal-cardiac control or cardiovagal baroreflex sensitivity in young healthy subjects. European Journal of Applied Physiology, 93(5), 719-725. https://doi.org/10.1007/s00421-004-1243-x

Díaz-García, J., Clemente-Suárez, V., Fuentes, J., & Villafaina, S. (2023). Combining HIIT Plus Cognitive Task Increased Mental Fatigue but Not Physical Workload in Tennis Players. Applied Sciences, 13, 7046. https://doi.org/10.3390/app13127046

Esco, M. R., Olson, M. S., Williford, H. N., Blessing, D. L., Shannon, D., & Grandjean, P. (2010). The relationship between resting heart rate variability and heart rate recovery. Clinical Autonomic Research, 20(1), 33-38. https://doi.org/10.1007/s10286-009-0033-2

Faigenbaum, A. D., Lloyd, R. S., & Myer, G. D. (2013). Youth Resistance Training: Past Practices, New Perspectives, and Future Directions. Pediatric Exercise Science, 25(4), 591-604. https://doi.org/10.1123/pes.25.4.591

Figueiredo, T., Willardson, J. M., Miranda, H., Bentes, C. M., Reis, V. M., & Simão, R. (2015). Influence of Load Intensity on Postexercise Hypotension and Heart Rate Variability after a Strength Training Session. The Journal of Strength & Conditioning Research, 29(10). https://doi.org/10.1519/JSC.0000000000000954

Granacher, U., Lesinski, M., Büsch, D., Muehlbauer, T., Prieske, O., Puta, C., Gollhofer, A., & Behm, D. G. (2016). Effects of Resistance Training in Youth Athletes on Muscular Fitness and Athletic Performance: A Conceptual Model for Long-Term Athlete Development. Frontiers in Physiology, Volume 7-2016. https://doi.org/10.3389/fphys.2016.00164

Güngör, A. K., Topçu, H., Aldhahi, M. I., Al-Mhanna, S. B., & Gülü, M. (2024). Resistance Training to Muscle Failure with Variable Load Intensities: Implications for Post-Exercise Blood Pressure and Heart Rate Variability in Trained Men. Journal of Clinical Medicine, 13(8). https://doi.org/10.3390/jcm13082296

Haff, G. G., Stone, M., O'Bryant, H. S., Harman, E., Dinan, C., Johnson, R., & Han, K.-H. (1997). Force-Time Dependent Characteristics of Dynamic and Isometric Muscle Actions. The Journal of Strength & Conditioning Research, 11(4). https://doi.org/10.1519/1533-4287(1997)011<0269:FTDCOD>2.3.CO;2

Heffernan, K., Fahs, C., Shinsako, K., Jae, S. Y., & Fernhall, B. (2007). Heart rate recovery and heart rate complexity following resistance exercise training and detraining in young men. American journal of physiology. Heart and circulatory physiology, 293, H3180-6. https://doi.org/10.1152/ajpheart.00648.2007

Holloszy, J. O., & Coyle, E. F. (1984). Adaptations of skeletal muscle to endurance exercise and their metabolic consequences. Journal of Applied Physiology, 56(4), 831-838. https://doi.org/10.1152/jappl.1984.56.4.831

Kingsley, J. D., & Figueroa, A. (2016). Acute and training effects of resistance exercise on heart rate variability. Clinical Physiology and Functional Imaging, 36(3), 179-187. https://doi.org/10.1111/cpf.12223

Lee, D., Brellenthin, A. G., Lanningham-Foster, L. M., Kohut, M. L., & Li, Y. (2024). Aerobic, resistance, or combined exercise training and cardiovascular risk profile in overweight or obese adults: The CardioRACE trial. European Heart Journal, 45(13), 1127-1142. https://doi.org/10.1093/eurheartj/ehad827

Lemos, S., Figueiredo, T., Marques, S., Leite, T., Cardozo, D., Willardson, J. M., & Simão, R. (2018). Effects of Strength Training Sessions Performed with Different Exercise Orders and Intervals on Blood Pressure and Heart Rate Variability. International journal of exercise science, 11(2), 55-67. https://doi.org/10.70252/YSMQ3374

Lopes, F., Pereira, F., Reboredo, M., Castro, T., Vianna, J., Jr, J., & Silva, L. (2007). Reduction of heart rate variability in middle-aged individuals and the effect of strength training. Brazilian Journal of Physical Therapy, 11, 113-119. https://doi.org/10.1590/S1413-35552007000200005

Melo, R. C., Quitério, R. J., Takahashi, A. C. M., Silva, E., Martins, L. E. B., & Catai, A. M. (2008). High eccentric strength training reduces heart rate variability in healthy older men. British Journal of Sports Medicine, 42(1), 59. https://doi.org/10.1136/bjsm.2007.035246

Nuzzo, J. L. (2020). The Case for Retiring Flexibility as a Major Component of Physical Fitness. Sports Medicine, 50(5), 853-870. https://doi.org/10.1007/s40279-019-01248-w

Paavolainen, L., Häkkinen, K., Hämäläinen, I., Nummela, A., & Rusko, H. (1999). Explosive-strength training improves 5-km running time by improving running economy and muscle power. Journal of Applied Physiology, 86(5), 1527-1533. https://doi.org/10.1152/jappl.1999.86.5.1527

Reena Tiwari, Ravindra Kumar, Sujata Malik, Tilak Raj, & Punit Kumar. (2021). Analysis of Heart Rate Variability and Implication of Different Factors on Heart Rate Variability. Current Cardiology Reviews, 17(5), 11-20. https://doi.org/10.2174/1573403X16999201231203854

Robinson, K., Riley, N., Owen, K., Drew, R., Mavilidi, M. F., Hillman, C. H., Faigenbaum, A. D., Garcia-Hermoso, A., & Lubans, D. R. (2023). Effects of Resistance Training on Academic Outcomes in School-Aged Youth: A Systematic Review and Meta-Analysis. Sports Medicine, 53(11), 2095-2109. https://doi.org/10.1007/s40279-023-01881-6

Selig, S. E., Carey, M. F., Menzies, D. G., Patterson, J., Geerling, R. H., Williams, A. D., Bamroongsuk, V., Toia, D., Krum, H., & Hare, D. L. (2004). Moderate-intensity resistance exercise training in patients with chronic heart failure improves strength, endurance, heart rate variability, and forearm blood flow. Journal of Cardiac Failure, 10(1), 21-30. https://doi.org/10.1016/S1071-9164(03)00583-9

Stanley, J., Peake, J. M., & Buchheit, M. (2013). Cardiac Parasympathetic Reactivation Following Exercise: Implications for Training Prescription. Sports Medicine, 43(12), 1259-1277. https://doi.org/10.1007/s40279-013-0083-4

Thompson, W. R. (2022). Worldwide Survey of Fitness Trends for 2022. ACSM's Health & Fitness Journal, 26(1). https://doi.org/10.1249/FIT.0000000000000732

Tomlinson, D. J., Erskine, R. M., Morse, C. I., Winwood, K., & Onambélé-Pearson, G. (2016). The impact of obesity on skeletal muscle strength and structure through adolescence to old age. Biogerontology, 17(3), 467-483. https://doi.org/10.1007/s10522-015-9626-4

Walker, S., Häkkinen, K., Newton, R. U., Markworth, J. F., Pundir, S., Haff, G. G., Cameron-Smith, D., & Blazevich, A. J. (2020). Acute responses of comprehensive gonadosteroids and corticosteroids to resistance exercise before and after 10 weeks of supervised strength training. Experimental Physiology, 105(3), 438-448. https://doi.org/10.1113/EP087995