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Study Protocol

Comparison of Acute Heart Rate Variability (HRV) Response Between Neuromuscular and Metabolic Training in Collegiate High-Intensity Intermittent Sport Athletes: A Pilot Study Protocol

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Abstract

Background: Heart rate variability (HRV) is a common tool for assessing autonomic nervous system activity and monitoring training load in athletes. However, limited research has explored how HRV responds to different forms of resistance training, particularly in high-intensity intermittent sports like basketball and football. **Objective**: This study aims to compare the acute HRV responses between neuromuscular and metabolic training in collegiate athletes involved in high-intensity intermittent sports. **Study Design**: A comparative cross-sectional study with a quasi-experimental crossover design will be employed. **Methods**: Collegiate athletes will be randomly assigned to undergo both neuromuscular and metabolic training sessions with a one-week wash-out period in between. HRV data will be recorded using the Polar H10 chest strap during each session. **Data Analysis:** Descriptive statistics will summarize salient participant characteristics and HRV measurements. Inferential analysis will use paired t-tests or Wilcoxon signed-rank tests based on normality, assessed via the Kolmogorov-Smirnov test. All statistical analyses will be conducted using the IBM SPSS (ver.25) with a confidence interval set. at 95% and a critical α equal to 0.05. **Expected Results**: Neuromuscular training is expected to elicit higher low-frequency (LF) power and an increased LF/HF ratio, reflecting greater sympathetic activation, while metabolic training is expected to show lower LF power and a decreased LF/HF ratio, indicating a more balanced autonomic response. These findings will offer insights into the differential autonomic impacts of these training modalities.

Key Words: *heart rate variability, high-intensity intermittent sports, metabolic training, neuromuscular training*

INTRODUCTION

Intermittent sports are characterized by bursts of high-intensity activity interspersed with periods of rest, either scheduled or unscheduled.[1] These sports often involve repeated multidirectional efforts that highlight their intermittent nature.[2] Sports like basketball and football exemplify this, with active phases (such as dribbling or passing) alternating with more passive moments (like free throws or penalty kicks). The performance in these sports relies heavily on both anaerobic and aerobic energy systems.[3] High-intensity movements predominantly engage the anaerobic system, while the aerobic system supports recovery and sustains performance throughout the duration of the match. Consequently, athletes participating in high-intensity intermittent sports require training programs that address both metabolic and neuromuscular demands.[4]

Neuromuscular factors, including the ability to change direction rapidly and enhance jump performance, are critical for success in such sports. Neuromuscular training focuses on optimizing the coordination between the nervous and muscular systems, which influences dynamic stability, plyometric ability, speed, and agility.[5] This type of training improves intermuscular and intramuscular coordination by involving low-volume, high-intensity exercises.[6] Positive adaptations from neuromuscular training include enhanced stretch-shortening cycle function, better muscle fiber responsiveness, and improved movement efficiency.[6] This training approach increases reflex activity, motor unit synchronization, and motor unit recruitment, all of which are crucial for generating powerful, coordinated movements.[7] Metabolic training, on the other hand, emphasizes increasing an athlete's lactate threshold, which refers to the point where lactic acid starts to accumulate in muscles.[8] Adaptations to this type of training include improved muscle-buffering capacity, greater capillarization, and an elevated lactate threshold, all of which delay the onset of muscle fatigue. These adaptations allow athletes to tolerate greater volumes of work, which is essential for maintaining performance in high-intensity intermittent sports like basketball and football.[8] While there is no single gold standard approach, these types of training differ in key variables, neuromuscular training typically uses low repetitions, high intensity, and longer rest periods, whereas metabolic training employs higher repetitions, moderate intensity, and shorter rest intervals.[6] Combining both neuromuscular and metabolic training approaches within a periodized program is essential for optimizing the performance of athletes in these sports.

Monitoring the effects of different types of training on athletes is crucial, and current evidence suggests that the autonomic nervous system (ANS) plays a significant role in mediating exercise-related physiological responses.[9] Specifically, training load influences cardiac autonomic modulation, with autonomic activity reflecting an individual's response to the type and intensity of exercise.[10] Research indicates that the parasympathetic component of the ANS recovers more slowly following high-intensity exercises, while sympathetic dominance persists to compensate for this delayed recovery.[11] This suggests that neuromuscular training, which emphasizes low volume and high intensity, may result in heightened sympathetic activity and diminished parasympathetic recovery when compared to metabolic training.[10] As a result, autonomic responses to these two types of training may differ substantially in high-intensity intermittent sports.

In the realm of neuroscience, electroencephalogram (EEG) is often considered the gold standard for monitoring neural responses during exercise due to its non-invasiveness and temporal precision.[12] However, heart rate variability (HRV) is a simpler and more accessible tool for tracking autonomic activity.[9] HRV provides insights into how athletes adapt to training loads by reflecting ANS activity.[14] In particular, HRV analysis is commonly used to assess cardiac autonomic function in both healthy and clinical populations. Within the context of sports, HRV helps quantify an athlete's physical fitness, training status, and perceived stress or fatigue.[15] Given its accessibility and utility, HRV data can guide coaches and sports scientists in designing, implementing, or adjusting training programs to optimize athlete performance.

HRV data can be assessed using both linear and non-linear methods, typically derived from the R-R intervals between successive heartbeats. The R-R interval refers to the time between successive R-waves (the peak of the QRS complex) on an electrocardiogram, representing one cardiac cycle.[16] The most commonly used linear methods are time-domain and frequency-domain analyses.[15] Time-domain analysis measures the variability in successive heartbeats, while frequency-domain analysis assesses how power is distributed across different frequency bands, particularly ultra-low, very-low, low, and high-frequency bands.[15] In this study, we will utilize the low-frequency (LF) band, which ranges from 0.04 to 0.15 Hz, to assess sympathetic activity. This parameter is a reliable indicator of sympathetic dominance, especially in long-term recordings.[15] Both time-domain and frequency-domain analysis will be utilized in this study.

HRV has gained popularity in sports science as an effective tool for monitoring training responses. Previous research has linked HRV to training parameters like exercise intensity and duration.[18] Research indicates that HRV has an inverse relationship with exercise intensity, and that HRV tends to return to baseline approximately 30 minutes after exercise, with quicker recovery observed following lower-intensity workouts.[18] Additionally, exercise duration can negatively impact HRV, particularly during more challenging sessions.[18] Despite its extensive use in endurance and aerobic training, little is known about HRV responses in strength training settings.[18]

Additionally, a study investigated HRV responses to resistance training but failed to differentiate between neuromuscular and metabolic training modalities.[19] Furthermore, research on HRV in high-intensity intermittent sports remains limited. This pilot study aims to explore preliminary differences in HRV responses to neuromuscular and metabolic training among high-intensity intermittent sport athletes. Specifically, it seeks to observe potential HRV patterns before, during, and after training sessions to inform future research on autonomic regulation. Additionally, the study aims to assess the feasibility of using HRV as a monitoring tool for training responses in high-intensity intermittent sports.

Methodology

Study Design. This pilot study is part of a bigger project that explores acute HRV response to two different types of training. A cross-sectional comparative study design will be employed to fulfill the study's objectives. A crossover design will then be utilized to obtain HRV response to the two types of training, wherein participants will receive two training exposures (neuromuscular and metabolic types of training). The order in which they are exposed to these two types of training would be randomized for each participant, as seen in Figure 1.

This study protocol was registered in the Philippine Health Research Registry with Registry ID: PHRR241206-007807 and Open Science Framework with identifier: DOI 10.17605/OSF.IO/T2ZCV.

Ethical Considerations. The University of Santo Tomas-College of Rehabilitation Sciences Ethics Review Committee (UST-CRS-ERC) reviewed and approved this study SI-2024-004**.**

Sampling Design

Sample Size. In conducting a pilot study, determining an exact sample size is not strictly necessary due to its exploratory nature and primary aim of assessing feasibility rather than achieving statistical significance.

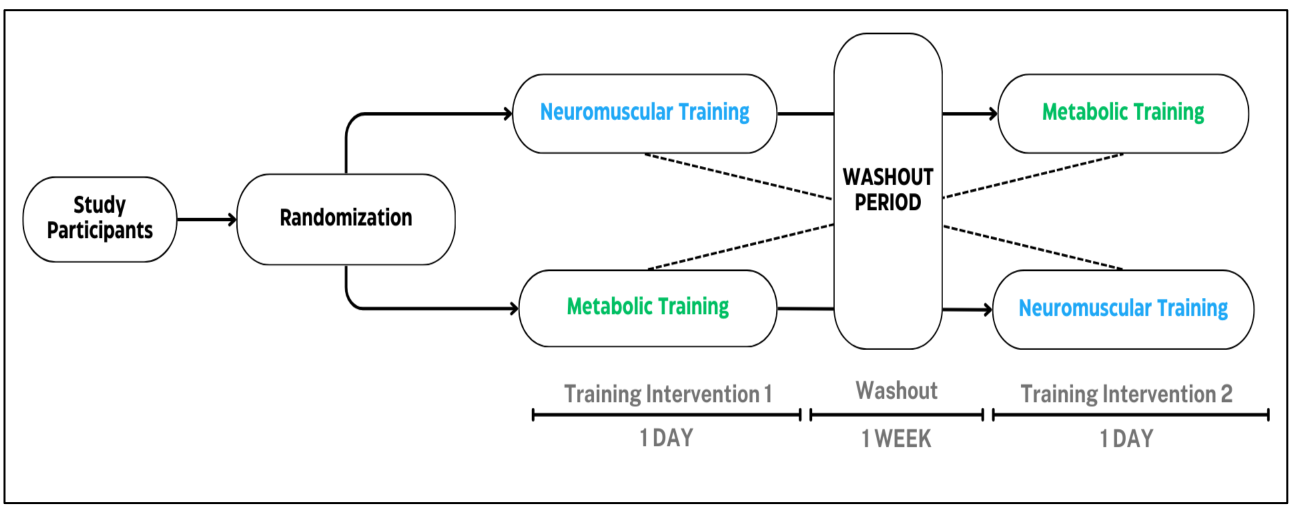

Figure 1. Design of Methodology

The focus is on evaluating the study's methodology, data collection processes, and practicality of measuring HRV responses. However, to ensure sufficient variability and meaningful insights, the researchers aim to recruit a minimum of 12 participants.[20] This sample size should provide enough data to observe potential trends and patterns in HRV responses between neuromuscular and metabolic training, while still allowing for manageable logistics within the scope of a pilot study.

Sampling Method. The researchers will employ a non-probability convenience sampling method to recruit participants. This approach involves intentionally selecting individuals who meet specific eligibility criteria established by the study. This method ensures that participants are chosen based on their relevance to the research objectives, maximizing the likelihood of obtaining meaningful insights into the HRV responses to neuromuscular and metabolic training.

Participants. All study participants will be recruited from the University of Santo Tomas (UST) Men's and Women's Senior Basketball and Football teams. The researchers will assess their eligibility using the set criteria below:

Setting. This study will occur at the Sports Science (SPS) Laboratory within the UST Quadricentennial Pavilion, Manila, Philippines.

Instrumentation

Polar H10 Chest Strap for HRV Monitoring. The Polar H10 chest strap heart rate monitor will be used in this research to detect the R-R interval of the participants. The Polar H10 monitor has been proven to be a valid and reliable tool to monitor R-R interval for resting conditions (PRE: $r = 0.95$, $rc = 0.95$, $ICC_{3,1} = 0.95$, POST: $r = 0.86$, $rc = 0.84$, $ICC_{3,1} = 0.85$) and in incremental exercise ($r > 0.93$, $rc > 0.93$, $ICC_{3,1} > 0.93$)[23], ($r = 0.997$, $p>0.001$)[24], using ECG as a criterion measure. In this study, HRV metrics in both frequency-domain and time-domain analysis will be utilized. In the frequency-domain analysis, LF/HF ratio will specifically be analyzed, reflecting autonomic balance and regulation. In the time-domain analysis, RMSSD and pNN50 index measures will also be used as these estimate the short-term parasympathetic component with useful statistical properties.

Exposure. The study will involve two types of resistance training, designed by an EXOS-certified performance specialist shown in Table 3 to Table 8. Neuromuscular training will consist of a power session with low volume and high intensity [6], while metabolic training will involve a hypertrophy session with high volume and low intensity.[6] Neuromuscular training aims to increase power output, and hypertrophy training aims to increase muscle size through prolonged submaximal effort.

Each session will include a warm-up, main workout, and cool-down, structured as full-body workouts. Intensity will be based on perceived exertion or 1RM with bilateral exercises.

The warm-up will use the RAMP protocol (Raise, Activate, Mobilize, Potentiate) for general preparation.[25,26] Cool-downs will consist of static stretches of the activated muscles.

Data Gathering Procedures. Before data collection begins, informed consent forms and the Physical Activity Readiness Questionnaire Form (PARQ+) from the International Standard for Pre-Participation Screening will be collected from the participants. This shall screen participants with pre-existing medical conditions as indicated in the criteria for exclusion and screen for such conditions that could hinder their performance during the study. Along with this, participants will be given a profile sheet to gather basic information such as their full name, age, gender, and sport. Additional questions specific to the study will be included, such as the number of training years of experience in their sport and in the gym or weights room, current medications/supplementation, and their latest 1-repetition maximum (1RM) test result in the barbell squat, barbell bench press, and barbell deadlift. Participants will then be oriented to the sessions and data collection procedures, as shown in Figure 3.

The first and second data collection sessions will be scheduled with a one-week washout period in between. This washout period is designed to minimize carryover effects between the neuromuscular and metabolic training exposures

Table 1. Inclusion and Exclusion Criteria

INCLUSION	EXCLUSION
UST Basketball and Football athletes that are on the official roster (Team A and B) A.Y. 2024-2025.	Athletes who are currently injured or have suffered an injury 6 months prior to the study *This timeframe is the usual general timeframe for most injuries to recover before returning to athletic activities.*[22]
UST Basketball and Football athletes aged 18-25 years old *This is the age range eligible for a collegiate athlete in UST.*	Athletes with pre-existing medical conditions (e.g., metabolic or cardiovascular)
Resistance training age greater than 1 year *Athletes would have been able to experience all types of resistance training in one annual strength training plan.*[3]	Athletes who currently take medication or supplementation that can affect the cardiovascular system (e.g., beta blockers, ACE inhibitors, vasodilators) *These can have physiological effects on the cardiovascular system that could alter the HRV response during the experiment.*[3, 24]

and ensure participants return to baseline levels before the next session. Resistance training can cause acute muscle soreness and affect performance,[27] with recovery varying among individuals. Studies indicate that most participants return to baseline performance within 72 hours ,[28] while muscle force generally recovers within 24 hours to 7 days, depending on the protocol and individual factors.[28, 29] Other research suggests recovery may take 1 to 10 days.[27, 30]

Along with the wash-out period, it is vital that during data collection, participants are in a similar state across testing sessions due to various physiological and environmental factors that may influence performance. Researchers will provide pre-test guidelines based on the Australian Institute of Sport (AIS)[33] protocols as shown in Table 2. Moreover, participants will complete a pre-test questionnaire to gather relevant information from participants prior to testing. A Hooper and Mackinnon questionnaire [34] will also be given to assess fatigue and stress levels before each data collection session.

The data collection session will involve several key components: baseline, training exposure, and recovery intervention. HRV will first be measured at baseline using the Polar H10 to establish pre-training metrics before proceeding to the training exposure. The training exposure will also consist of some subcomponents: a warm-up, the main training session, which is either metabolic or neuromuscular, and a cool-down. Lastly, the recovery intervention will be provided to each participant and will be administered by the collaborating study in this project. All of these subcomponents will be separated by a 30-second transition period.

Plan for Data Management & Analysis. Once data management procedures are completed, data analysis will be conducted using the following:

Nevrokard Advanced HRV Software. Data from the Polar H10 and recorded by the Elite HRV application will be exported and analyzed using Nevrokard Advanced HRV software. This software imports ECG data and exports results, analyzing HRV with good correlation to other HRV software such as Kubios HRV and HRV Soft.[32] Nevrokard will assess HRV metrics, including LF/HF ratio in the frequency domain and SD1/SD2 in the non-linear domain.

Statistical Analysis. Statistical analyses will be performed using IBM SPSS (ver. 25), with a confidence interval set at 95% and a critical α of

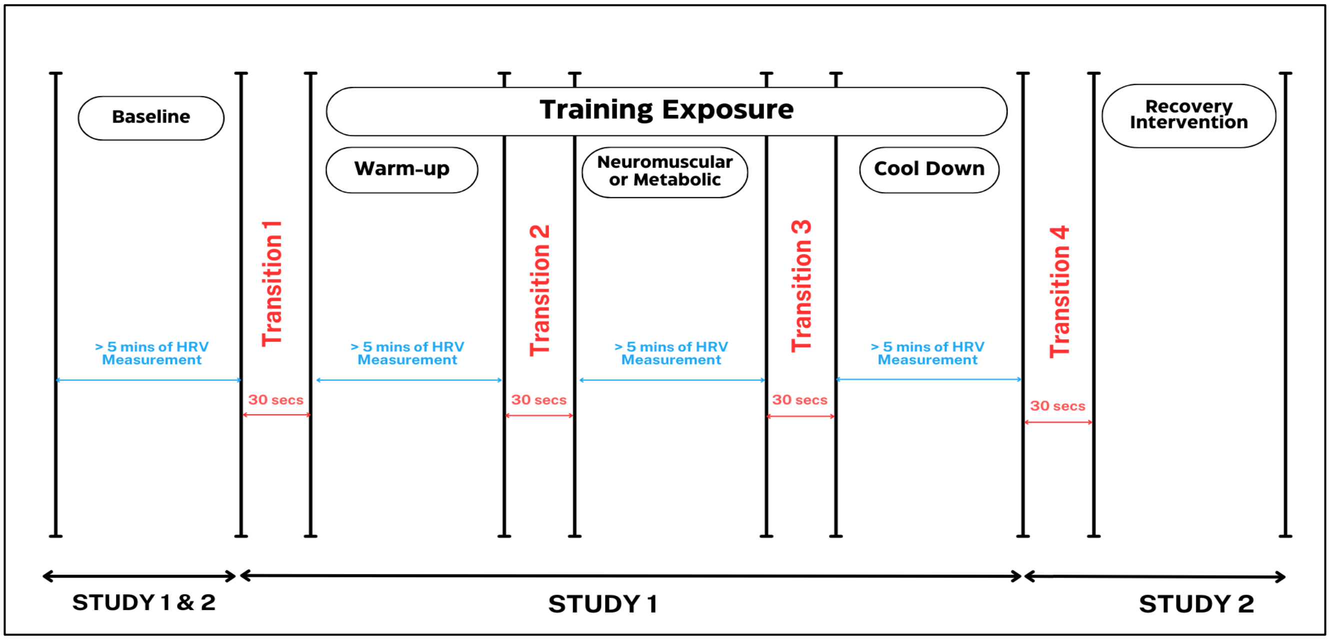

Figure 2. Diagram of the actual Data Collection Procedure

0.05. Descriptive statistics (mean, median, mode, standard deviation, range) will describe participant characteristics. The Kolmogorov-Smirnov test will assess normality.

Depending on the normality test results, either a paired t-test or a Wilcoxon signed-rank test will be used to determine significant differences. The t-test is preferred for normally distributed data, while the Wilcoxon test is used for non-normal distributions, offering greater power in such cases.[35]

EXPECTED RESULTS

It is anticipated that the study will demonstrate distinct differences in HRV responses between neuromuscular and metabolic training in high-intensity intermittent sports athletes. Neuromuscular training, which involves high-intensity and low-volume exercises, is expected to elicit a higher LF power and a corresponding increase in the LF/HF ratio, indicating greater sympathetic nervous system activation. This is consistent with the demands of neuromuscular training that prioritize explosive movements and strength development. In contrast, metabolic training, characterized by higher volume and moderate intensity, is likely to show a more balanced autonomic response, reflected in lower LF power and a decreased LF/HF ratio, signifying a relatively higher parasympathetic influence. These expected outcomes will provide insight into how different types of strength training impact autonomic regulation, helping to inform the use of HRV as a monitoring tool in athletic training programs.

Individual Author's Contributions

All authors contributed equally to this study protocol.

Disclosure Statement

The authors will self-fund this review.

Conflicts of Interest

Author ING is part of the PJAHS Editorial Board.

References

1. Baker LB, Rollo I, Stein KW, Jeukendrup A. Acute effects of carbohydrate supplementation on intermittent sports performance. Nutrients. 2015;7(7):5733-5763. DOI:10.3390/nu7075249.
2. Dolci F, Hart NH, Kilding AE, Chivers P, Piggott B, Spiteri T. Physical and energetic demand of soccer: a

brief review. Strength and Conditioning Journal. 2020;42(3):70-77. DOI:10.1519/SSC.0000000000000533.

3. Roso-Moliner A, Mainer-Pardos E, Cartón-Llorente A, Nobari H, Pettersen SA, Lozano D. Effects of a neuromuscular training program on physical performance and asymmetries in female soccer. Frontiers in Physiology. 2023;14. DOI:10.3389/fphys.2023.1171636.

4. Ferioli D, Bosio A, Bilsborough JC, La Torre A, Tornaghi M, Rampinini E. The preparation period in basketball: training load and neuromuscular adaptations. International Journal of Sports Physiology and Performance. 2018;13(8):991-999. DOI:10.1123/ijspp.2017-0434.

5. Panagoulis C, Chatzinikolaou A, Avloniti A, Leontsini D, Deli CK, Draganidis D, et al. In-season integrative neuromuscular strength training improves performance of early-adolescent soccer athletes. Journal of Strength and Conditioning Research. 2020;34(2):516-526. DOI:10.1519/JSC.0000000000002938.

6. Bompa T, Buzzichelli CA. Periodization training for sports PDF file. 3rd ed. Human Kinetics, Inc.; 2015.

7. Harrison PW, James LP, McGuigan MR, Jenkins DG, Kelly VG. Resistance priming to enhance neuromuscular performance in sport: evidence, potential mechanisms and directions for future research. Sports Medicine. 2019 Oct;49(10):1499-514.

8. Schoenfeld BJ. The M.A.X. muscle plan PDF file. 2nd ed. Human Kinetics, Inc.; 2022.

9. Makivic B, Nikic M, Willis M. Heart rate variability (HRV) as a tool for diagnostic and monitoring performance in sport and physical activities. Journal of Exercise Physiology Online. 2013;16(3):103-131.

10. Iellamo F, Lucini D, Volterrani M, Casasco M, Salvati A, Gianfelici A, et al. Autonomic nervous system responses to strength training in top-level weight lifters. Physiological Reports. 2019;7(20). DOI:10.14814/phy2.14233.

11. Casonatto J, Tinucci T, Dourado A, Polito MD. Cardiovascular and autonomic responses after exercise sessions with different intensities and durations. Clinics (Sao Paulo). 2011;66(3):453-458. DOI:10.1590/s1807-59322011000300016.

12. Subhani AR, Xia L, Malik AS. Association of autonomic nervous system and EEG scalp potential during playing 2D Grand Turismo 5. 34th Annual International Conference of the IEEE (Institute of Electrical and Electronics Engineers) Engineering in Medicine and Biology Society. 2012:3420-3423. DOI:10.1109/EMBC.2012.6346700.

13. Tiwari R, Kumar R, Malik S, Raj T, Kumar P. Analysis of heart rate variability and implication of different factors on heart rate variability. Current Cardiology Reviews. 2021;17(5). DOI:10.2174/1573403X16999201231203854.

14. Stepanyan L, Lalayan G. Heart rate variability features and their impact on athletes' sports performance. Journal of Physical Education and Sport. 2023;23(8):2156-2163. DOI:10.7752/jpes.2023.08247.

15. Mamlouk AC, Younès M, Zarrouk F, Shephard RJ, Bouhlel E. Heart rate variability and stress perception: the influence of physical fitness. Science & Sports. 2021;36(4):276-283. DOI:10.1016/j.scispo.2021.02.001.

16. Reed MJ, Robertson CE, Addison PS. Heart rate variability measurements and the prediction of ventricular arrhythmias. Qjm. 2005 Feb 1;98(2):87-95.

17. Lutfi MF. Review article: heart rate variability. Sudan Journal of Medical Sciences. 2011;6(1):43-50. Available from:

18. Lundstrom CJ, Foreman NA, Biltz G. Practices and applications of heart rate variability monitoring in endurance athletes. International Journal of Sports Medicine. 2023;44(1):9-19. DOI:10.1055/a-1864-9726.

19. Thamm A, Freitag N, Figueiredo P, Doma K, Rottensteiner C, Bloch W, Schumann M. Can heart rate variability determine recovery following distinct strength loadings? A randomized cross-over trial. International Journal of Environmental Research and Public Health. 2019;16(22):4353. DOI:10.3390/ijerph16224353.

20. Julious S. Sample size of 12 per group rule of thumb for a pilot study. Pharmaceutical Statistics. 2005;4(4):287-291. DOI:10.1002/pst.185.

21. Kisner C, Colby LA. Therapeutic exercise: foundations and techniques. 6th ed. F. A. Davis Company; 2012.

22. Scarpignato C, Blandizzi C. Adverse effects of nonsteroidal anti-inflammatory drugs on the cardiovascular system. In: NSAIDs and Aspirin. 2016:61-89. DOI:10.1007/978-3-319-33889-7_5.

23. Schaffarczyk M, Rogers B, Reer R, Gronwald T. Validity of the Polar H10 sensor for heart rate variability analysis during resting state and incremental exercise in recreational men and women. Sensors. 2022;22(17):6536. DOI:10.3390/s22176536

24. Gilgen-Ammann R, Schweizer T, Wyss T. RR interval signal quality of a heart rate monitor and an ECG Holter at rest and during exercise. European Journal of Applied Physiology. 2019;119:1525-1532. DOI:10.1007/s00421-019-04142-5

25. National Strength and Conditioning Association. Essentials of Strength Training and Conditioning PDF file. 4th ed. Haff GG, Triplett NT, editors. Human Kinetics, Inc.; 2016.

26. Jeffreys I. The Warm-Up: Maximize Performance and Improve Long-Term Athletic Development PDF file. Human Kinetics, Inc.; 2017.

27. Jones E, Bishop PA, Richardson MT, Smith JF. Stability of a practical measure of recovery from resistance training. Journal of Strength and Conditioning Research. 2006;20(4):756-759. DOI:10.1519/R-15554.1

28. McLester JR, Bishop P, Smith J, Wyers L, Dale B, Kozusko J, et al. A series of studies—a practical protocol for testing muscular endurance recovery. Journal of Strength and Conditioning Research. 2003;17(2):259-273. DOI:10.1519/1533-4287(2003)017<0259:ASOSPP>2.0.CO;2

29. Häkkinen K. Neuromuscular fatigue and recovery in male and female athletes during heavy resistance exercise. International Journal of Sports Medicine. 1993;14(2):53-59. DOI:10.1055/s-2007-1021146.

30. Clarkson PM, Nosaka K, Braun B. Muscle function after exercise-induced muscle damage and rapid adaptation. Medicine and Science in Sports and Exercise. 1992;24(5):512-520.

31. Shaffer F, Ginsberg JP. An overview of heart rate variability metrics and norms. Frontiers in Public Health. 2017;5:258. DOI:10.3389/fpubh.2017.00258

32. Rajalakshmi R, Akila B, Tharion E. Intra-class correlation among heart rate variability analysis software across different physiological postures. Indian Journal of Physiology and Pharmacology. 2015;59(1):2-8.

33. Tanner R, Gore C. Physiological Tests for Elite Athletes. 2nd ed. Human Kinetics; 2013.

34. Moalla W, Fessi MS, Farhat F, Nouira S, Wong DP, Dupont G. Relationship between daily training load and psychometric status of professional soccer players. Research in Sports Medicine. 2016;24(4):387–394. DOI:10.1080/15438627.2016.1239579

35. Maggio S, Sawilowsky SS. A new maximum test via the dependent samples t-test and the Wilcoxon signed-ranks test. Applied Mathematics. 2014;5:110-114. DOI:10.4236/am.2014.51013.