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Study Protocol

Investigating the Influence of Neurobiofeedback Intervention on Heart Rate Variability vis-à-vis Recovery of UAAP Collegiate Basketball and Football Athletes: A Pilot Study Protocol

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Abstract

Background: Recovery is essential for high-intensity intermittent sports athletes to achieve optimal performance. Heart rate variability (HRV) serves as a marker of the autonomic nervous system, which also measures the parasympathetic regulation that facilitates recovery. Neurofeedback (NBF) intervention, combined with deep breathing and mental imagery, presented positive results in facilitating parasympathetic reactivation. However, limited studies exist in investigating the influence of the NBF intervention on HRV parameters and recovery, specifically in high-intensity intermittent sports athletes. **Objective:** This pilot study aims to investigate the effects and influence of neurobiofeedback intervention on recovery via the use of HRV of UAAP Collegiate Basketball and Football Athletes. **Study Design:** The research will be done with a Quasi-experimental one-group pretest-posttest study design. **Methodology:** Participants will undergo a neurobiofeedback intervention following neuromuscular and metabolic training. Data is collected with a Polar H10 HRM Chest Strap connected to an Elite HRV monitoring application and will be analyzed by Kubios HRV software. **Statistical Analysis:** Descriptive statistics will be computed for participant characteristics. Kolmogorov-Smirnov test ($p > 0.05$) will assess normality. Two-way repeated-measures ANOVAs will examine NBF effects across exercise types, with Bonferroni-corrected pairwise comparisons and trend analysis for the main effects and non-significant but clinically relevant patterns. All analyses will be done using SPSS v25. **Expected Results:** It is expected that the neurobiofeedback intervention will have an effect and influence by eliciting a lower LF/HF ratio and SD1/SD2, suggesting a facilitated reactivation of the parasympathetic nervous system, promoting recovery after undergoing neuromuscular or metabolic training..

Key Words: *Heart Rate Variability, Intermittent sport athletes, Neurobiofeedback, Deep Breathing, Mental Imagery*

INTRODUCTION

Optimal performance is accompanied by an optimal recovery. The pursuit of peak athletic performance is always an interplay between training and recovery to help athletes maximize their competitive results. This effect of recovery is especially true for high-intensity intermittent sports athletes whose sports involve intermittent bursts of high-intensity exercises, complex sports-specific skills, and cognitive tasks over a long period of time like basketball and football (soccer).[1,2] The athlete's rest and recovery allows their physiological systems to repair and recover resulting in restoration of performance-related abilities.[3] Additionally, it helps prevent overreaching and/or overtraining, which is important to prevent injuries, as both neuromuscular and metabolic needs are also trained during high-intensity intermittent sports.[3,4]

Basketball and football athletes both undergo high-intensity, intermittent training and exhibit similar mean values in certain characteristics, such as bone mass and maximal oxygen consumption. Both sports emphasize the development of cardiorespiratory endurance, muscular strength, aerobic and anaerobic power, and most of all, agility. Due to these shared physical demands and training characteristics, one study concluded that there is no significant difference in strength levels between basketball and football players.[5,6,7]

Neuromuscular and metabolic training are both trained during high-intensity intermittent sports, but have different functions. Neuromuscular training focuses on exercises that enhance motor skills, wherein the relationship between how the nervous system facilitates the muscular system to produce optimal movements is trained.[8,9] Meanwhile, metabolic training focuses on having a high volume training in a shorter period of time by combining high repetitions (approximately 15-30 repetitions per set) and short rest intervals (approximately 30 seconds or less). Both of these require an exertion of intermittent short bursts, which can result in overtraining, fatigue, a decrease in performance, and, worse, injuries.[1,2,3,8] An example for this case is a study about soccer players wherein a decline in maximal voluntary contraction (MVC) force, jump height, and sprint time up to 36% for up to 96 hours after the match. The decline can be linked to having an incomplete recovery is likely to be detrimental to intermittent-sports and sports-specific skill performance.[10] Furthermore, basketball players also exhibited a decrease in performance when under the influence of fatigue. A study stated that upon performing basic elements of movement kinematics and parameters in basketball, under the influence of fatigue, elite basketball players tend to compensate for force production on their shoulders and elicit decreased movement on the pelvis, increasing injury risks.[11] Thus, optimal rest and recovery are needed.[4,8,12]

One way to monitor recovery, specifically post-exercise recovery of athletes, is through heart rate variability (HRV), a non-invasive assessment of autonomic function and changes in short-term and long-term endurance exercise training in both leisure sports activity and high-performance training. HRV is also being investigated as a diagnostic marker of overreaching and overtraining, as it monitors performance, training response, fatigue, readiness, and recovery for athletes.[13] Higher HRV is associated with positive physiological adaptations, improved health, and greater self-regulatory capacity in athletes.[14,15] Besides its positive physiological impacts, it also has components that involve psychological and social processes.[4,14] The impact of post-exercise recovery on psychological components can be measured through the fluctuation in time between adjacent heartbeats.[16] HRV reflects the regulation of autonomic balance of its two branches, which are the sympathetic nervous system, responsible for the body's *fight-or-flight* response, and the parasympathetic nervous system, responsible for the body's *rest and digest* response.[3]

To monitor HRV, two primary domains can be used. The *Time-domain* and the *Frequency-domain,* along with *non-linear measurements.* Specifically, frequency-domain and nonlinear methods measure the LF/HF Ratio and SD1/SD2. On the one hand, the non-linear domain indicates heart rhythm patterns that are less sensitive to confounding variances and are best suited for a short-term analysis. On the other hand, the frequency domain directly reflects the sympathovagal tone, indicating the balance between the sympathetic and parasympathetic nervous system.[17] The LF/HF Ratio uses both Low Frequency (LF) power and High Frequency (HF) power. LF is produced by both the SNS and PNS activity, while the HF power is reflected by the PNS activity. Thus, a low LF/HF ratio reflects parasympathetic dominance, while a high LF/HF ratio reflects sympathetic dominance.[17,18] For the Standard Deviation, hence SD or more specifically the SD1 and SD2, is analyzed by the usage of a Poincaré plot. SD1 measures short-term HRV correlating with HF power, while SD2 measures short- and long-term HRV correlating with LF power. The ratio of the two, SD1/SD2, also measures autonomic balance, correlating with the LF/HF ratio. The dynamic relationship between the PNS and SNS plays an important role in determining an athlete's recovery, as PNS dominance is associated with rest and recovery.[17]

In relation to the recovery effects of higher HRV to the neurological and biological systems, an intervention called neurobiofeedback can be used. This is a method wherein people can self-regulate through continuous use of visualization and/or body control which also helps in SNS to PNS control to achieve homeostasis. The most commonly used neurobiofeedback techniques in sports are breathing exercises and imagery. Breathing exercises play a vital role in recovery by reducing physiological stress responses. One type of breathing is slow deep breathing which helps athletes quickly return to a calm and recovered state by regulating the autonomic nervous system. In contrast, rapid breathing can increase stress and anxiety, impairing the recovery process.[18,19] In a sport-setting, slow and controlled deep breathing presented an accelerated and improved post-exercise HRV recovery in athletes stating parasympathetic reactivation.[18,20] Imagery techniques, or the mind-body relaxation technique, mental stimulation is done to achieve a desired goal. In sport setting, it is used as a relaxation technique to achieve the desired performance by activating the autonomic nervous system and by improving the aspects of planning and programming in mind.[21,22,23] Moreover, the combination of deep breathing and mental imagery has shown to result in parasympathetic reactivation and positive physiological responses,[21,22,24] making it a promising approach to enhance heart rate variability (HRV) and promote emotional regulation.[19]

In addition, HRV measurement requires a precise temporal standardization to yield meaningful data, especially when evaluating the autonomic nervous system recovery patterns in athletes.[25].These sequential conditions align with an established protocol as well in demonstrating a post-exercise HRV monitoring, which requires standardized time points to specifically reflect parasymphathetic reactivation, including a 5-minute recording for HRV analysis.[26, 27] This standardized approach ensures reliable data for assessing HRV changes over time. Lastly, recovery assessment through HRV should also occur at consistent intervals following workout cessation to properly track autonomic nervous system recovery patterns, allowing for a clearer understanding of how the body rebalances post-exercise.[28]

Although HRV and neurofeedback have been used for recovery, there is still limited research on their application in high-intensity intermittent sports. Most studies examining the combination of breathing and imagery as neurobiofeedback interventions have only been conducted on populations such as firefighters, rather than athletes. As a result, there is still an unestablished knowledge regarding specific high-intensity sport athletic populations with regards to HRV effects under neurofeedback interventions. Further limitations exist in terms of the duration of interventions, the presence or absence of breathing professionals, and the consistency of evidence supporting the benefits of breathing on athletic performance. For instance, while slow breathing has been shown to have positive physiological and psychological effects, more research is still needed to confirm if breathing techniques, mental imagery, or the combination of the two will be the most effective for the study. Moreover, there is still a lack of consensus on which recovery strategies are most effective, particularly for basketball players and there is no specific study done in the Philippines and on Filipino athletes as a population.[23] Hence, as a pilot study, it aims to serve as a preliminary investigation in assessing the influence and effects of a neurobiofeedback intervention on heart-rate variability in relation to recovery following neuromuscular and metabolic training. In addition, it seeks to observe HRV trends and patterns for proof of concept that may inform future research on using NBF intervention as a recovery tool for high-intensity intermittent sports.

Methodology

Study Design. The study will utilize a quasi-experimental one-group pretest-posttest design due to the absence of a control group, which deters a true experimental design. This will be utilized to meet the pilot study' objectives. The within-subjects design will then be utilized to control for differences in participants' HRV measurements. All participants will be exposed to the same NBF intervention protocol following a randomized training exposure, neuromuscular or metabolic, allowing for direct measurement of the effects of NBF intervention on recovery processes. Heart rate variability (HRV), the primary dependent variable, will be measured across four sequential conditions in the same participants: Condition 1, pre-workout baseline (PRE); condition 2, post-workout; condition 3, neurofeedback intervention; and condition 4, post-neurobiofeedback (POST). This comprehensive measurement will track autonomic nervous system function throughout the pre-workout up to post-neurofeedback intervention by measuring HRV at four distinct conditions, with particular focus on pre-workout (PRE) and post-NBF intervention (POST).[25]

This study protocol was registered in the Philippine Health Research Registry with PHRR Registry ID: PHRR241213-007828 and Open Science Framework with identifier: DOI 10.17605/OSF.IO/RQGAW.

Ethical Considerations. The University of Santo Tomas-College of Rehabilitation Sciences Ethics Review Committee (UST-CRS-ERC) reviewed and approved this study. No conflict of interest has been disclosed.

Sampling Design

Sample Size. The study aims to recruit not less than 12 participants, as indicated in the study conducted by Julious in 2005, establishing a minimum of 12 participants as a rule of thumb for pilot studies.[29]

Sampling Method. The researchers will utilize a non-probability purposive sampling method to recruit eligible participants for the study. This involved intentionally recruiting participants based on the eligibility criteria set by the researchers. The researchers will also utilize randomization via fish-bowl technique in assigning the participants regarding the sequence of the training protocols - Neuromuscular or Metabolic, to reduce potential order effects and biases.

Participants. The participants in this study will be recruited from the University of Santo Tomas (UST), specifically from the UST Men's and Women's Senior Basketball teams and the UST Men's Senior Football team. These athletes will be chosen due to their involvement in high-performance collegiate sports, where they regularly engage in intense physical activity and training. The focus on basketball and football is intentional, as both sports demand high-intensity efforts, making the athletes ideal candidates for studying the effects of neurobiofeedback on heart rate variability (HRV) and recovery. The researchers will assess their eligibility using the set criteria seen in Table 1.:

Setting. This study will be conducted in the Sports Science (SPS) Laboratory, located in the University of Santo Tomas, Quadricentennial Pavilion, Manila, Philippines. The Sports Science (SPS) Laboratory is equipped with the necessary gym equipment, mattresses, as well as a soundproofed room with temperature control and adequate lighting.

Data Gathering Tool

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. There is a high correlation found in the study for resting conditions (PRE: $r = 0.95$, $rc = 0.95$, $ICC3,1 = 0.95$, POST: $r = 0.86$, $rc = 0.84$, $ICC3,1 = 0.85$) and in incremental exercise ($r > 0.93$, $rc > 0.93$, $ICC3,1 > 0.93$). Significant bias is found during exercise for all variables ($p<0.001$). A study concluded that the practicability of the Polar H10, a mobile-based HRV recording setup, has comparable results to ECG.[33] Furthermore, another study tested the Polar H10 with an ECG Holter device. The research concluded that the Polar H10 had excellent RR interval signal quality during low- to high-intensity activities, suggesting its validity for detecting RR intervals in a wide range of activities ($r = 0.997$, $p>0.001$), between the two systems.[34] Lastly, Polar models have a high agreement with ECG during all intensity levels and could be used in future research when ECG is unavailable.[35, 36]

Elite HRV Application for Collecting HRV Data. The Elite HRV Application will be used in this research to record and collect the data from the Polar H10. This smartphone application presents to be a valid tool in measuring HRV indexes, wherein an extremely large relationship between Elite HRV and Kubios HRV 2.2 software was found in a study, suggesting a strong correlation

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 validity of the application (r = 0.92; CI 95% = 0.90–0.93, p < 0.0001).[37] Moreover, a previous validation study found no significant differences between Elite HRV and the Polar V800 across key HRV parameters (p > 0.05), as well as revealed minimal bias and narrow limits of agreement across all metrics, including mean heart rate [−0.003 (0.05 to −0.04)], mean RR [0.01 (−0.58 to 0.60)], SDNN [−0.01 (−0.32 to 0.30)], and RMSSD [−0.05 (−0.89 to 0.79)]. The findings demonstrated excellent agreement, with intra-class correlation coefficients exceeding 0.999 for all variables, supporting the validity and reliability of Elite HRV for field-based HRV assessment.[38]

Kubios HRV Software. Developed by the Biosignal Analysis and Medical Imaging Group at the Department of Physics, University of Kuopio, Finland, Kubios HRV is widely used in scientific research on cardiology, stress, and autonomic nervous system function. This software provides a comprehensive platform for researchers, clinicians, and health professionals to explore HRV data as it supports both time-domain and frequency-domain analysis.[39] Moreover, Kubios HRV supports real-time measurements, enabling immediate analysis of HRV data. This feature is particularly valuable for practical applications in biofeedback and sports performance monitoring. This software also presents with good correlation with other HRV software, namely Nevrokard Advanced HRV Software and HRV Soft, even in different physiological states.[40] Furthermore, it shows excellent reliability, Intra-rater (α =0.868) and Inter-rater (α =0.890) and Validity (r = 0.94) with R-R intervals calculated from ECG. Thus, studies confirm its use in the clinical environment and in scientific research.[41,42]

Intervention*.* The Neurobiofeedback (NBF) intervention is a combined deep breathing and mental imagery protocol. The NBF intervention script and administration will be directly taken from a study that consisted of combined slow deep breathing and guided imagery, which resulted in the maintenance of physical fitness, promoted heart rate recovery, and promoted parasympathetic reactivation.[43] Furthermore, the neurobiofeedback intervention is also verified by a licensed psychologist to ensure its relevance, clarity, comprehensiveness, and safety. The NBF intervention will last for 30 minutes per session[24], combined deep breathing and mental imagery, the first 15 minutes will be allotted for slow deep breathing, and the last 15 minutes will be allotted for a combination of deep breathing and mental imagery. For all the sessions, an individual session will be conducted per participant to ensure confidentiality, safety, and efficacy, to provide a controlled and secure environment that maximizes the effectiveness of the intervention.

The neurobiofeedback intervention will also be administered by a faculty researcher with a Master's degree in Clinical Psychology and will be assisted by three assigned student researchers inside a temperature-controlled environment set at 22 degrees Celsius, where participants will lie down on comfortable mattresses. The Clinical Psychologist will administer the NBF intervention while the three assigned student researchers will assist by noting down the observations, tracking the time, and making sure the environment remains controlled throughout the intervention.

Data Gathering Procedures. Before proceeding with the intervention, a profile sheet will be given to the participants to gather basic information and anthropometrics, such as their full name, age, gender, height, weight, and sport. Additional questions specific to the study will be included, such as the number of years of training experience in their sport and in the gym or weights room, lifestyle habits, and current medications or supplementation. Moreover, a Physical Activity Readiness Questionnaire (PARQ+) Form from the International Standard for Pre-Participation Screening will also be provided. This form will be used to screen participants for pre-existing medical conditions, as outlined in the exclusion criteria, and to identify any conditions that could hinder their performance during the study. Participants had to be cleared for exercise based on their responses in the PARQ+ form in order to participate in the study.

Data collection will occur across two sessions with a seven-day washout period interval to eliminate potential confounding effects between the exercise exposures of neuromuscular and metabolic exercises. This is to ensure that the participants return to their physiological baseline, as resistance exercises will induce acute effects like soreness of muscles and decrements in performance.[44] Other studies also stated that most participants return to baseline performance parameters within 72 hours, while forces of the muscle recover within 24 hours to 7 days, depending on the exercise intensity and individual capacity to recover.[45] Researchers will also provide and give pre-test guidelines from the Australian Institute of Sport (AIS) and pre-test questionnaires of Hooper and Mackinnon to fully assess the stress and fatigue levels of the participants before each session of the data collection.[46, 47]

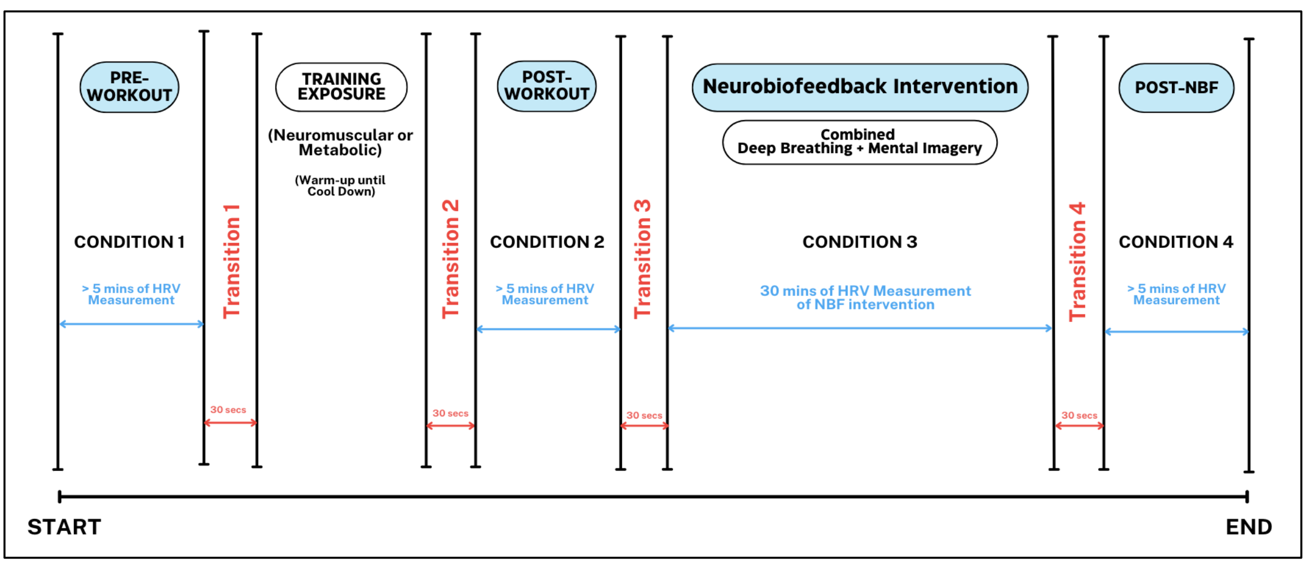

Figure 1. Actual Data Collection Procedure

The data collection session will involve four key sequential conditions: pre-workout baseline (condition 1), post-workout (condition 2), neurofeedback intervention (condition 3), and post-NBF (condition 4). Firstly, HRV measurement will start by recording the pre-workout data for >5 minutes using the Polar H10 to establish the baseline resting metrics before proceeding to the training exposure. Secondly, post-workout HRV data will be measured to capture the physiological response following neuromuscular or metabolic training. Thirdly, the participants will be asked to lie down in a supine position on a treatment mattress before being subjected to the neurobiofeedback intervention. Then, HRV measurement will be monitored during the neurofeedback (NBF) intervention, combined with deep breathing and mental imagery. Lastly, HRV measurement will be assessed again on post-NBF intervention to evaluate the influence of the neurofeedback intervention on recovery. All of these key sequential conditions will be separated by a 30-second transition period.

Data Management and Analysis. The data analysis will be utilized by the following:

HRV Data Analysis: Elite HRV and Kubios Software. HRV data will be recorded via the Polar H10 and Elite HRV app and will then be exported and analyzed using Kubios HRV software. Kubios software will assess the HRV frequency domain (LF, HF, LF/HF ratio) and non-linear domain (SD1, SD2, SD1/SD2 ratio). Kubios HRV software is a widely validated software for HRV analysis with excellent reliability and consistent with clinical standards.[48] For frequency-domain analysis, Kubios software utilizes autoregressive (AR) modeling with a 16 and 4 Hz resampling rate to derive the power components. Low Frequency (LF: 0.04-0.15Hz) and High Frequency (HF: 0.15-0.40 Hz) bands will be quantified in absolute power (ms^2) and normalized units (n.u), with LF/HR ratio calculated as the proportion between these two components to represent the sympathovagal balance. For non-linear analysis, the Poincaré plot parameters SD1 and SD2 will be calculated according to standard formulations, where SD1 represents standard deviation of instantaneous beat-to-beat RR short-term interval variability ($SD1=\sqrt{(SDSD^2/2)}$ and SD2 represents the standard deviation of continuous RR long-term interval variability ($SD2=\sqrt{(2SD\ RR^2-SDSD^2/2)}$. The SD1/SD2 ratio provides insight into the balance between the autonomic control components (SD1/SD2 ratio = SD1/SD2). SD1 correlates with RMSSD and indicates parasympathetic activity, while SD2 reflects sympathetic tone and long-term HRV. The SD1/SD2 ratio, similar to LF/HF, is viewed as a potential alternative for assessing autonomic balance.[16,17,40] The selected HRV parameters for this pilot study, specifically the frequency domain (LF, HF, LF/HF ratio) and non-linear domain (SD1, SD2, SD1/SD2ratio), are standard parameters readily available from Kubios software, as it provides an automated calculation of these parameters following data import.[48,49]

Table 2. Numerical chart of the Sequential Conditions and HRV Parameters

Numerical Sequence	Conditions	Timing	Duration
1	Pre-Workout (Condition 1)	Before Workout	>5 minutes
2	Post-Workout (Condition 2)	Immediately after Transition 2	>5 minutes
3	Neurobiofeedback Intervention	Immediately after Transition 3 (Intervention Proper)	30 minutes
4	Post-NBF Intervention	Immediately after Transition 4	>5 minutes

The automated algorithms in Kubios software ensure consistent and reliable calculation of the HRV parameters, allowing for efficient measurement of autonomic nervous system responses in athletic populations. [28,50,51,52]

Statistical Analysis*:* Descriptive statistics (mean, SD, frequencies) will be computed for participant characteristics and HRV data. Normality will be tested using the Kolmogorov-Smirnov test ($p > 0.05$). The Two-way repeated-measures ANOVAs will examine the effects of NBF across exercise types, with Bonferroni-corrected pairwise comparisons for the main effects. Effect sizes (ηp^2), statistical power (β), and $\alpha = 0.05$ will also be reported. Trends analysis will also be utilized to visualize, via line graphs, to highlight non-significant but clinically relevant patterns. All analyses will be done using SPSS v25.

EXPECTED RESULTS

It is expected that the neurobiofeedback intervention, combined breathing and mental imagery, will have an effect and influence on the recovery status of the high-intensity sports athletes by eliciting a lower LF/HF ratio and SD1/SD2, suggesting a facilitated reactivation of the parasympathetic nervous system promoting recovery after undergoing neuromuscular or metabolic training. Additionally, the researchers also anticipate observable trends and patterns for proof of concept in HRV parameters that may inform future utilization of the NBF intervention as a recovery tool for high-intensity intermittent sports collegiate athletes.

Individual Author's Contributions

All authors contributed equally to the development and writing of the protocol and to the eventual implementation, analysis, and reporting of this research.

Conflicts of Interest

IG is the editor-in-chief of PJAHS.

References

1. Baker LB, Rollo I, Stein K, Jeukendrup AE. Acute effects of carbohydrate supplementation on intermittent sports performance. Nutrients. 2015;7(7):5733–5763. DOI:10.3390/nu7075249
2. Dolci F, Hart N, 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. Bompa TO, Buzzichelli C. Periodization Training for Sports. 3rd ed. Human Kinetics; 2015.
4. Halson S. Recovery techniques for athletes. Australian Institute of Sports. 2013. Available from: https://www.gssiweb.org/docs/default-source/sse-docs/sse120-recoverytechniquesforathletes-halson_sse.pdf
5. Gligoroska JP, Pluncevic J, Popadic Gacesa J, Zivkovic V, Todorovic B, Djuric D, et al. Comparison of cardio-physiological and anthropometrical parameters between basketball and football players Research in Physical Education, Sport & Health. 2020 Jul 1;9(2).
6. Metaxas, T. et al. Preseason physiological profile of soccer and basketball players in a Chinese professional team. J Strength Cond Res. 2009;23(6):1551–1559. Available from:
7. Kumar A, Rajalakshmi R. Comparative study of cardiovascular fitness among football and basketball players. Int J Health Sci Res. 2023 Nov [cited 2025 May 17];13(11):17–22.
8. Akbar S, Soh KG, Nasiruddin NJM, Bashir M, Cao S, Soh KL. Effects of neuromuscular training on athletes physical fitness in sports: a systematic review. Frontiers in Physiology. 2022;13:939042. DOI:10.3389/fphys.2022.939042
9. 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;14:1171636. DOI:10.3389/fphys.2023.1171636
10. Minett GM, Duffield R. Is recovery driven by central or peripheral factors? A role for the brain in recovery following intermittent-sprint exercise. Frontiers in Physiology. 2014;5:24. doi:10.3389/fphys.2014.00024
11. Li F, Ma Y, Wang R, Wang Y, Zhang Y. Influence of fatigue on some kinematic parameters of basketball passing. Int J Environ Res Public Health. 2021 Jan;18(2):700.
12. Schoenfeld B. The M.A.X. Muscle Plan 2.0. 2nd ed. Human Kinetics; 2022.
13. Hottenrott K, Hoos O, Esperer HD. Herzfrequenzvariabilität und Sport. Herz. 2006;31(6):544–552. DOI:10.1007/s00059-006-2855-1
14. Perez-Gaido M, Lalanza JF, Parrado E, Capdevila L. Can HRV biofeedback improve short-term effort recovery? Implications for intermittent load sports. Applied Psychophysiology and Biofeedback. 2021;46(2):215–226. DOI:10.1007/s10484-020-09495-8
15. Plews DJ, Laursen PB, Stanley J, Kilding AE, Buchheit

M. Training adaptation and heart rate variability in elite endurance athletes: opening the door to effective monitoring. Sports Medicine. 2013;43(9):773–781. DOI:10.1007/s40279-013-0071-8

16. 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
17. Chen JL, Yeh DP, Lee JP, et al. Parasympathetic nervous activity mirrors recovery status in weightlifting performance after training. The Journal of Strength and Conditioning Research. 2011;25(6):1546–1552. DOI:10.1519/jsc.0b013e3181da7858
18. Migliaccio GM, Russo L, Marić M, Padulo J. Sports performance and breathing rate: what is the connection? A narrative review on breathing strategies. Sports. 2023;11(5):103. DOI:10.3390/sports11050103
19. Zhang Y, Du X, Liu F, Jing X, Wu B. The effects of guided imagery on heart rate variability in simulated spaceflight emergency tasks performers. BioMed Research International. 2015;2015:687020. DOI:10.1155/2015/687020
20. Laborde, S., Mosley, E., & Mertgen, A. (2019). Vagal tank theory: The three Rs of cardiac vagal control functioning–resting, reactivity, and recovery. Frontiers in Neuroscience, 12, 458.
21. Martinez J, Mourot L. Analysis of heart rate variability during a mental image session of a walk. Revista De Investigación. 2020;10(2). DOI:10.15332/2422474x/6229
22. Chrismas BCR, Taylor L, Thornton HR, Murray A, Stark G. External training loads and smartphone-derived heart rate variability indicate readiness to train in elite soccer. International Journal of Performance Analysis in Sport (Online). 2019;19(2):143–152. DOI:10.1080/24748668.2019.1578097
23. Mihajlovic M, Čabarkapa D, Cabarkapa DV, Philipp NM, Fry A. Recovery methods in basketball: a systematic review. Sports. 2023;11(11):230. DOI:10.3390/sports11110230
24. Biéchy JP, Charissou C, Gobert S, et al. The combination of deep breathing and mental imagery promotes cardiovascular recovery in firefighters. Ergonomics. 2021;64(10):1231–1242. DOI:10.1080/00140139.2021.1916606
25. Privitera G, Ahlgrim-Delzell L. Research methods for education. SAGE Publications; 2019. Available from: https://us.sagepub.com/sites/default/files/upm-binaries/89876_Chapter_13_Quasi_Experimental_and_Single_Case_Designs.pdf
26. Stanley, J., Peake, J. M., & Buchheit, M. (2013). Cardiac parasympathetic reactivation following exercise: implications for training prescription. Sports medicine, 43(12), 1259-1277.
27. Task Force of the European Society of Cardiology. (1996). Heart rate variability: standards of measurement, physiological interpretation and clinical use. Circulation, 93(5), 1043-1065.
28. Laborde, S., Mosley, E., & Thayer, J. F. (2017). Heart rate variability and cardiac vagal tone in psychophysiological research–recommendations for experiment planning, data analysis, and data reporting. Frontiers in Psychology, 8, 213.
29. Julious SA. Sample size of 12 per group rule of thumb for a pilot study. Pharmaceutical Statistics: The Journal of Applied Statistics in the Pharmaceutical Industry. 2005 Oct;4(4):287-91.
30. Kisner C, Colby LA. Therapeutic Exercise: Foundations and Techniques. 6th ed. F.A. Davis Company; 2012.
31. Scarpignato C, Blandizzi C. Adverse effects of nonsteroidal anti-inflammatory drugs on the cardiovascular system. In: NSAIDs and Aspirin. Springer; 2016:61–89. DOI:10.1007/978-3-319-33889-7_
32. Tamargo J, Rosano G, Walther T, et al. Gender differences in the effects of cardiovascular drugs. European Heart Journal - Cardiovascular Pharmacotherapy. 2017;3(3):163–182. DOI:10.1093/ehjcvp/pvw042
33. 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
34. 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 Apr 19. DOI:10.1007/s00421-019-04142-5
35. Ruiz-Alias S, et al. Examining weekly heart rate variability changes: a comparison between monitoring methods. Sports Engineering. 2022 Apr 29. DOI:10.1007/s12283-022-00371-8
36. Khushhal A, Nichols S, Evans W, et al. Validity and reliability of the Apple Watch for measuring heart rate during exercise. Sports Medicine - International Open. 2017;1(6):E206–E211. DOI:10.1055/s-0043-120195
37. Perrotta AS, Jeklin AT, Hives BA, Meanwell LE, Warburton DE. Validity of the Elite HRV smartphone application for examining heart rate variability in a field-based setting. Journal of Strength and Conditioning Research. 2017;31(8):2296–302. DOI:10.1519/JSC.0000000000001841
38. Chhetri P, Shrestha L, Mahotra NB. Validity of Elite-HRV smartphone application for measuring heart rate variability compared to Polar V800 heart rate monitor. Journal of Nepal Health Research Council. 2021;19(53):678–82. DOI:10.33314/jnhrc.v19i04.3949
39. Attar ET. Improved HRV analysis in ECG data: A comparative study using MATLAB code, Kubios, and gHRV. Journal of King Abdulaziz University -

Engineering Sciences. 2024;34(1):6. DOI:10.4197/Eng.34-1.6

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

41. Gabani V, Murugan S. Reliability and validity of Kubios HRV smart phone application as measures of heart rate variability. Int J Curr Res Rev. 2024;16(6):7-10. DOI:10.31782/ijcrr.2024.16602

42. Almeida LV, Santos-de-Araújo AD, Cutrim RC, Tavarez RRJ, Borghi-Silva A, Pereira FHF, Pontes-Silva A, Rêgo AS, Rocha DS, Marinho RS, Dibai-Filho AV, Bassi-Dibai D. Intra- and interrater reliability of short-term measurement of heart rate variability on rest in individuals post-COVID-19. Int J Environ Res Public Health. 2022 Oct 20;19(20):13587. DOI:10.3390/ijerph192013587.

43. Guzik P, Piskorski J, Krauze T, Schneider R, Wesseling KH, Wykretowicz A, Wysocki H. Correlations between the Poincaré plot and conventional heart rate variability parameters assessed during paced breathing. Journal of Physiological Sciences. 2007;57(1):63–71. DOI:10.2170/physiolsci.RP005506

44. 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

45. 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

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

47. 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

48. Tarvainen MP, Niskanen JP, Lipponen JA, Ranta-Aho PO, Karjalainen PA. Kubios HRV—heart rate variability analysis software. Comput Methods Programs Biomed. 2014;113(1):210–220. DOI:10.1016/j.cmpb.2013.07.024

49. Lipponen JA, Tarvainen MP. A robust algorithm for heart rate variability time series artefact correction using novel beat classification. J Med Eng Technol. 2019;43(3):173–181. DOI:10.1080/03091902.2019.1640306

50. Makivić B, Nikić Djordjević M, Willis MS. Heart rate variability (HRV) as a tool for diagnostic and monitoring performance in sport and physical activities. J Exerc Physiol Online. 2013;16(3):103-131.

51. Flatt AA, Esco MR. Validity of the ithlete™ smart phone application for determining ultra-short-term heart rate variability. J Hum Kinet. 2013;39:85-92. DOI:10.2478/hukin-2013-0071.

52. Pereira LA, Flatt AA, Ramirez-Campillo R, Loturco I, Nakamura FY. Assessing shortened field-based heart-rate-variability-data acquisition in team-sport athletes. Int J Sports Physiol Perform. 2016;11(2):154-158. DOI:10.1123/ijspp.2015-0038